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SEISMIC TESTING OF EARTH DYKE AT DECEW FALLS GS

Report No 88-11-K

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ABSTRACT

Seismic surveys were conducted on and near the earth dyke at DeCew Falls GS to determine the depth of various strata and bedrock. This program was conducted to provide additional data with respect to the geotechnical investigation to determine the overall stability of the reservoir embankment.

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TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	SEISMIC EQUIPMENT AND SETUP	1
3.0	RESULTS AND CALCULATIONS	1
4.0	DISCUSSION	3
5.0	CONCLUSION	4
ACKNOWLEDGMENTS		4
FIGURE 1	PLAN VIEW SHOWING LOCATIONS OF SEISMIC SURVEYS AT DECEW FALLS GS EMBANKMENT	5
TABLE 1	SEISMIC TESTING RESULTS - DECEW FALLS GS	6
APPENDIX A	PLOTS OF SURVEY DATA	9
DISTRIBUTION		last page

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SEISMIC TESTING OF EARTH DYKE
AT DECEW FALLS GS

1.0 INTRODUCTION

A seismic survey was conducted at various locations on and near the DeCew Falls GS earth dyke, by the Rock Sciences Section (Civil Research Department) during the months of August and September, 1987. The purpose of the program was to provide additional input into the geotechnical investigation aimed at determining the overall stability of the earth dyke. This report provides the locations of the surveys, as requested by the Geotechnical Department, as well as the velocities and depths of the various strata detected during the testing program. In an effort to verify the measurements from each location, the survey was conducted in reverse as well. The results were based on our best possible interpretation of the data, since some of the surveys were affected by wind, construction and traffic noise.

2.0 SEISMIC EQUIPMENT AND SETUP

The seismic equipment used was the Geometrics/Nimbus ES-1210, 12 channel Signal Enhancement Seismograph. The seismograph was powered by a 12-volt battery. An array of 12 geophones in line was used to conduct each survey. A sledge hammer was used to generate a signal by striking a steel plate, which had previously been placed on the ground. The seismograph recorded the first time arrivals for all twelve geophones. Subsequent to enhancing and printing out the data, the steel plate was moved to the opposite end of the geophone line, where the survey was repeated in reverse. The separation of the geophones was generally 4 m (13 ft), except in areas where distance limitations occurred (ie, down slope).

3.0 RESULTS AND CALCULATIONS

The locations of all of the seismic surveys conducted are shown in Figure 1. They are numbered from S1 (A and B) to S18 (A and B). S1 indicates survey 1,

while S18 indicates survey 18 for example. The letter "A" behind the survey number indicates the first or normal survey with the source at one end of the seismic array, while the letter "B" indicates the second or reverse survey, with the source placed at the opposite end of the same array. A complete summary of the results indicating the test number, hammer source location, direction of array, depths, velocities and assumed material is located in Table 1.

The first time arrivals from all of the seismic surveys were determined from the seismograph printouts and plotted against geophone distances. These graphs are all shown in Appendix 1. For convenience, the velocity (V) and depth (Z) for each layer is indicated where possible.

The velocity (V) is determined by:

$$V = \frac{D_2 - D_1}{T_2 - T_1}$$

where: D_2 = Distance 2
D_1 = Distance 1
T_2 = Time 2 corresponding to D_2
T_1 = Time 1 corresponding to D_1

The depth (Z1) to the bottom of the first layer is determined by:

$$Z1 = \frac{X_c}{2}\sqrt{\frac{V_2 - V_1}{V_2 + V_1}}$$

where: X_c = critical distance for V_1 and V_2
V_1 = velocity of first layer
V_2 = velocity of second layer

The depth (Z2) of the second layer is determined by:

$$Z2 = \frac{V_3 T_{i3}}{2}\left[\frac{1}{\sqrt{\left(\frac{V_3}{V_2}\right)^2 - 1}}\right] - Z1\left[\frac{\sqrt{\left(\frac{V_3}{V_1}\right)^2 - 1}}{\sqrt{\left(\frac{V_3}{V_2}\right)^2 - 1}}\right]$$

where: V_3 = velocity of third layer
T_{i3} = time intercept for V_3

Velocities for the overburden ranged from 587 ft/s (179 m/s) to 2000 ft/s (610 m/s) with an average value of 1252 ft/s (382 m/s). Velocities for the clay fill ranged from 1333 ft/s (406 m/s) to 2889 ft/s (881 m/s) with an

average value of 1941 ft/s (592 m/s). Velocities for the till ranged from 2889 ft/s (881 m/s) to 8667 ft/s (2642 m/s) with an average value of 5106 ft/s (1556 m/s). Velocities for the bedrock ranged from 7142 ft/s (2177 m/s) to 16250 ft/s (4953 m/s) with an average value of 11,880 ft/s (3621 m/s).

4.0 DISCUSSION

Survey S3 (A and B) located at chainage 24+00, just south of the deepest part of the valley (perpendicular to the dyke), has provided bedrock depths averaging 40.2 ft (12.3 m) for the normal and inverse directions. Even though bedrock data were based on a limited number of data points, there appears to be a rapid drop in bedrock elevation from north to south based on these results and those obtained in surveys S10, S11 and S12, conducted on the north side of the valley.

Survey S4 (A and B) located between chainages 24+00 and 24+45 at the bottom of the dyke and running parallel to the dyke axis, provided no data on bedrock depth, due to physical limitations in increasing the lateral extent of the array.

Survey S5 (A and B) was not included in this report because of difficulties in analyzing the results. This was due to the complex topography in the valley.

Surveys S6 (A and B) and S7 (A and B) were both conducted down the slope of the dyke at chainages 23+40 and 24+00 respectively. Survey S6 (A and B) was located in an area of tension cracks, while survey S7 (A and B) was undertaken in an area where tension cracks were not observed. A comparison of overburden results indicated no significant differences between the two surveys. This suggests that either the equipment is not sensitive enough to pick up potential differences or that the cracks are not significant enough to be detected.

Surveys S8 (A and B) and S9 (A and B) were both conducted down the slope of the dyke at chainages 7+00 and 6+00 respectively. Survey S8 (A and B) was undertaken at the location of the failed area, while survey S9 (A and B) was conducted in an area north of the influenced zone. Overburden velocities in the failed area were slightly higher but not significant enough to draw any conclusions.

Surveys S10 (A and B) and S11 (A and B) were performed back to back, while survey S12 (A and B) overlapped part of S10 (A and B) and part of S11 (A and B). The depth to bedrock in survey S10 (A and B) was 3.5 ft (1.1 m) deeper than that found in survey S11 (A and B). The normal survey S12A shows a bedrock depth difference of 6.8 ft (2.1 m) compared to the reverse survey S12B. These three surveys suggest that the depth to bedrock increases rapidly from north to south in this location.

Surveys S17 (A and B) and S18 (A and B) all provide similar and realistic velocity values for the overburden and underlying till. The remainder of the profile becomes questionable and may be attributed to the effects of the pavement on the nearby roadway.

5.0 CONCLUSION

A seismic survey was conducted on and near the earth dyke at the DeCew Falls Generating Station in St. Catharines, Ontario. This project was undertaken to provide further information with respect to a geotechnical investigation to determine the overall stability of the reservoir embankment. The results obtained appear to be realistic for all surveys except for those conducted along DeCew Road, which may have been affected by the presence of the pavement. Surveys in the valley area suggest a pronounced decrease in the bedrock elevation.

ACKNOWLEDGMENTS

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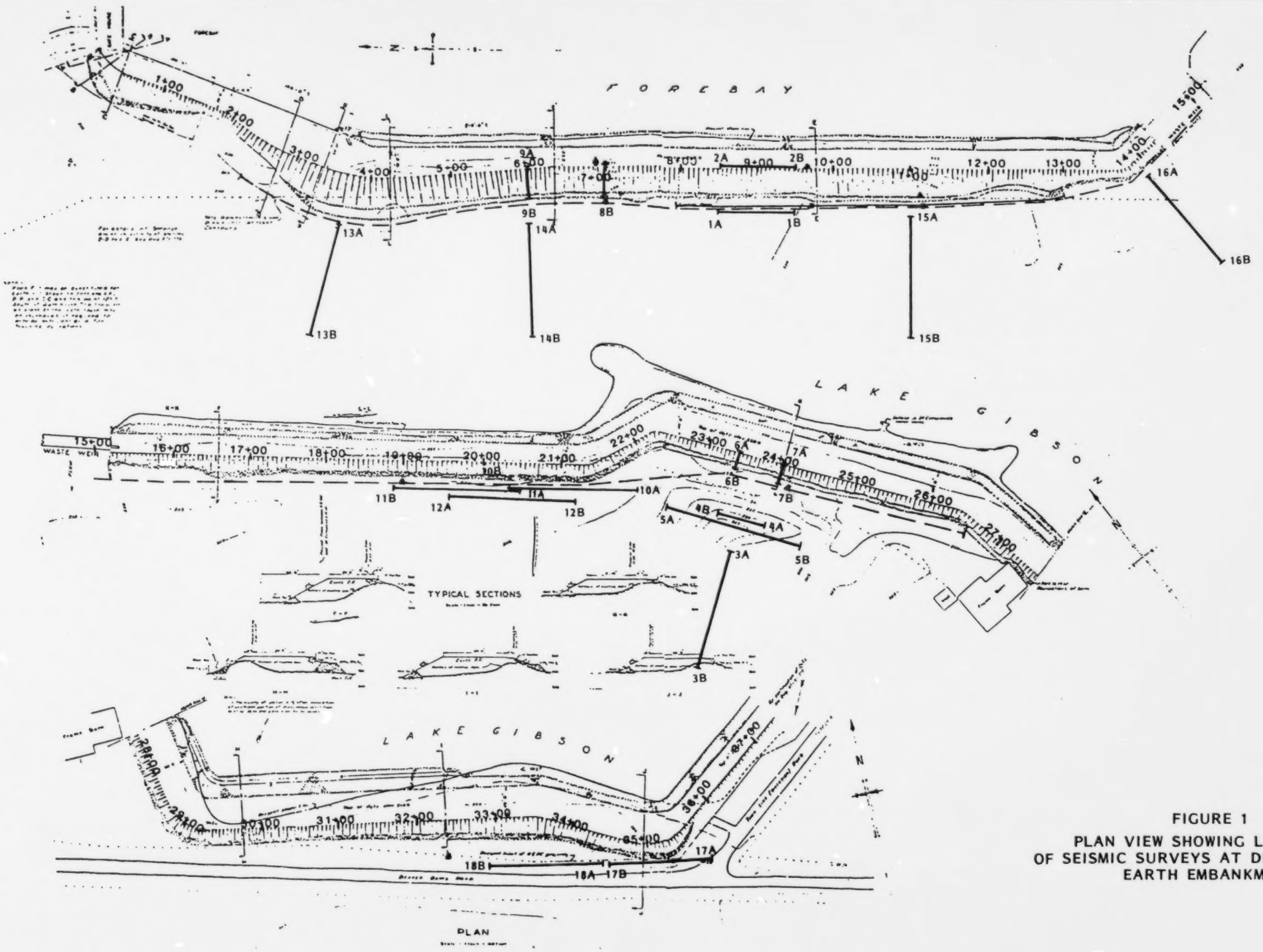

FIGURE 1
PLAN VIEW SHOWING LOCATIONS
OF SEISMIC SURVEYS AT DECEW FALLS GS
EARTH EMBANKMENT

Base map: Hydro Electric Power Commission of Ontario
Dwg. File No. 47-e-337

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TABLE 1 - SEISMIC TESTING - DECEW FALLS GS

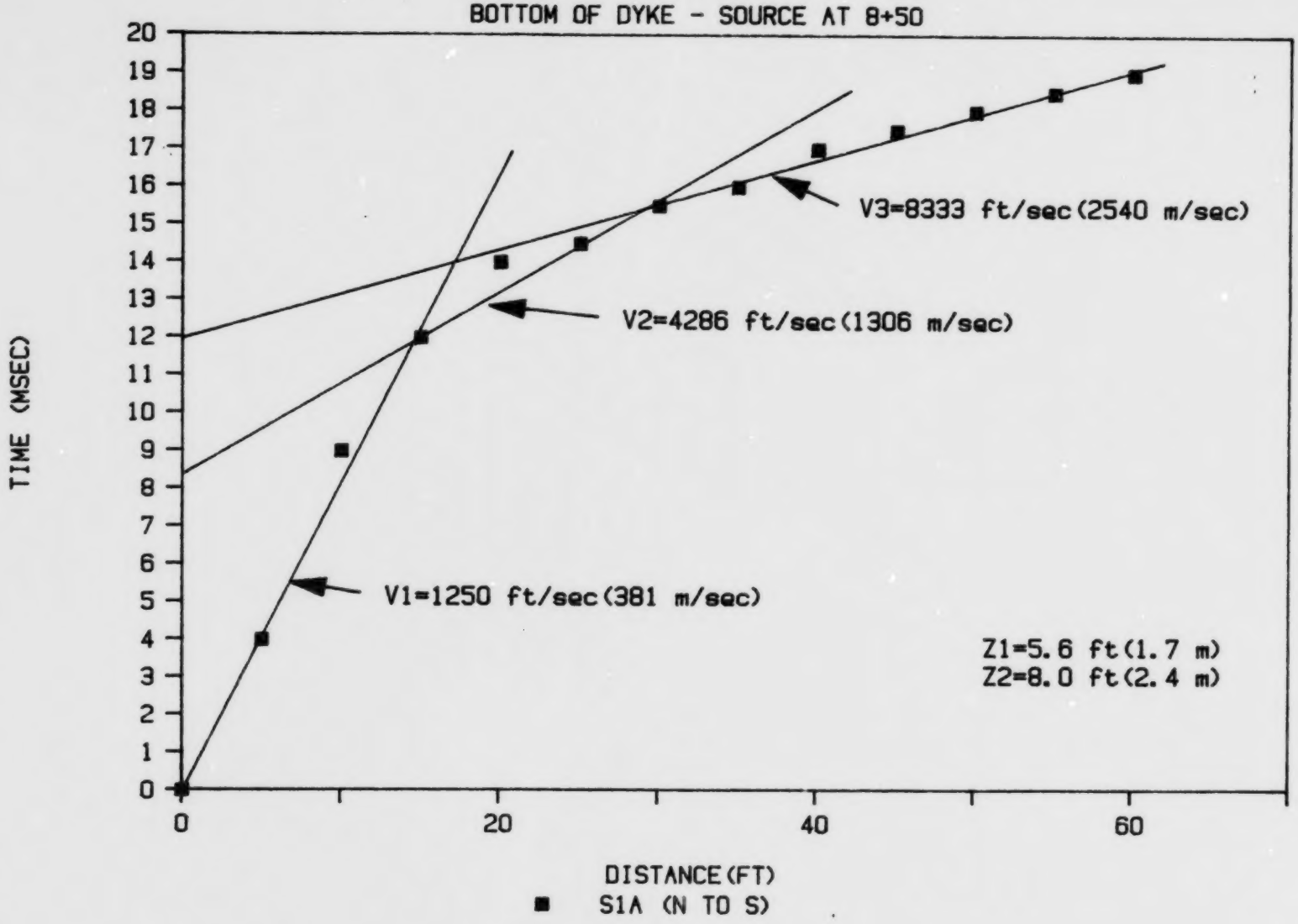
SEISMIC TEST NUMBER	HAMMER SOURCE LOCATION	DIRECTION OF ARRAY	DEPTH RANGE FT (M)	MATERIAL VELOCITY FT/SEC (M/SEC)	ASSUMED MATERIAL	COMMENTS
S1A	8+50	N TO S	0-5.6(0-1.7)	V1=1250 (381)	O/B	BOTTOM OF DYKE
			5.6-13.6(1.7-4.1)	V2=4286 (1306)	TILL	
			13.6-(4.1-)	V3=8333 (2540)	BEDROCK	
S1B	9+50	S TO N	0-4.4(0-1.3)	V1=1020 (311)	O/B	BOTTOM OF DYKE
			4.4-12.9(1.3-3.9)	V2=4939 (1475)	TILL	
			12.9-(3.9-)	V3=7142 (2177)	BEDROCK	
S2A	8+50	N TO S	0-5.7(0-1.7)	V1=587 (179)	O/B	TOP OF DYKE
			5.7-19.8(1.7-6.0)	V2=2889 (881)	CLAY FILL	
			19.8-(6.0-)	V3=4358 (1328)	TILL	
S2B	10+19	S TO N	0-6.2(0-1.9)	V1=650 (198)	O/B	TOP OF DYKE
			6.2-20.8(1.9-6.3)	V2=2080 (634)	CLAY FILL	
			20.8-(6.3-)	V3=4857 (1479)	TILL	
S3A	24+00	E TO W	0-5.5(0-1.7)	V1=1300 (396)	O/B	PERP. TO DYKE
			5.5-41.0(1.7-12.5)	V2=6500 (1981)	TILL	
			41.0-(12.5-)	V3=13500 (4115)	BEDROCK	
S3B	24+00	W TO E	0-4.3(0-1.3)	V1=1250 (381)	O/B	PERP. TO DYKE
			4.3-39.3(1.3-12.0)	V2=6667 (2032)	TILL	
			39.3-(12-)	V3=13333 (4064)	BEDROCK	
S4A	24+00	S TO N	0-5.9(0-1.8)	V1=1250 (381)	O/B	BOTTOM OF DYKE
			5.9-(1.8-)	V2=5455 (1663)	TILL	
S4B	23+45	N TO S	0-5.5(0-1.7)	V1=1429 (436)	O/B	BOTTOM OF DYKE
			5.5-(1.7-)	V2=5185 (1580)	TILL	
S6A	23+40	E TO W	0-6.0(0-1.8)	V1=1200 (366)	O/B	ON DYKE SLOPE
			6.0-(1.8-)	V2=2000 (610)	CLAY FILL	
S6B	23+40	W TO E	0-6.2(0-1.9)	V1=1154 (352)	O/B	ON DYKE SLOPE
			6.2-(1.9-)	V2=1846 (563)	CLAY FILL	
S7A	24+00	E TO W	0-3.8(0-1.2)	V1=1143 (348)	O/B	ON DYKE SLOPE
			3.8-(1.2-)	V2=1500 (457)	CLAY FILL	
S7B	24+00	W TO E	0-3.5(0-1.1)	V1=1132 (345)	O/B	ON DYKE SLOPE
			3.5-(1.1-)	V2=1333 (406)	CLAY FILL	
S8A	7+00	E TO W		V1=1400 (427)	O/B	ON DYKE SLOPE
S8B	7+00	W TO E	0-7.4(0-2.3)	V1=1556 (474)	O/B	ON DYKE SLOPE
			7.4-(2.3-)	V2=4118 (1255)	TILL	

S9A	6+00	E TO W		V1=1200 (366)	O/B	ON DYKE SLOPE
S9B	6+00	W TO E	0-8.3(0-2.5)	V1=1263 (385)	O/B	ON DYKE SLOPE
			8.3-(2.5-)	V2=3600 (1097)	TILL	
S10A	22+00	S TO N	0-7.4(0-2.3)	V1=1214 (370)	O/B	BOTTOM OF DYKE
			7.4-22.8(2.3-7.0)	V2=8667 (2642)	TILL	
			22.8-(7.0-)	V3=13000 (3962)	BEDROCK	
S10B	20+30	N TO S	0-6(0-1.8)	V1=1238 (377)	O/B	BOTTOM OF DYKE
			6-23.6(1.8-7.2)	V2=6500 (1981)	TILL	
			23.6-(7.2-)	V3=11111 (3387)	BEDROCK	
S11A	20+49	S TO N	0-6.6(0-2)	V1=1182 (360)	O/B	BOTTOM OF DYKE
			6.6-16.7(2-5.1)	V2=6500 (1981)	TILL	
			16.7-(5.1-)	V3=10833(3302)	BEDROCK	
S11B	18+93	N TO S	0-7.5(0-2.3)	V1=1238 (377)	O/B	BOTTOM OF DYKE
			7.5-18.7(2.3-5.7)	V2=6118 (1865)	TILL	
			18.7-(5.7-)	V3=13333 (4064)	BEDROCK	
S12A	19+65	N TO S	0-7.6(0-2.3)	V1=1182 (360)	O/B	BOTTOM OF DYKE
			7.6-20.6(2.3-6.3)	V2=7429 (2264)	TILL	
			20.6-(6.3-)	V3=16250 (4953)	BEDROCK	
S12B	21+21	S TO N	0-6(0-1.8)	V1=1182 (360)	O/B	BOTTOM OF DYKE
			6-27.4(1.8-8.3)	V2=6500 (1981)	TILL	
			27.4-(8.3-)	V3=14769 (4502)	BEDROCK	
S13A	3+75	E TO W	0-4.8(0-1.5)	V1=1529 (466)	O/B	PERP. TO DYKE
			4.8-12.9(1.5-4.0)	V2=5200 (1585)	TILL	
			12 9-(4.0-)	V3=13000 (3387)	BEDROCK	
S13B	3+75	W TO E	0-3.1(0-0.9)	V1=2000 (610)	O/B	PERP. TO DYKE
			3.1-18.8(1.2-5.7)	V2=4618 (1408)	TILL	
			18.8-(5.7-)	V3=8254 (2516)	BEDROCK	
S14A	6+00	E TO W	0-4.8(0-1.5)	V1=1300 (396)	O/B	PERP. TO DYKE
			4.8-12.4(1.5-3.8)	V2=4330 (1320)	TILL	
			12.4-(3.8-)	V3=11685 (3562)	BEDROCK	
S14B	6+00	W TO E	0-4.1(0-1.2)	V1=1238 (377)	O/B	PERP. TO DYKE
			4.1-15.7(1.2-4.7)	V2=2889 (881)	TILL	
			15.7-(4.7-)	V3=14857 (4528)	BEDROCK	
S15A	11+00	E TO W	0-4.6(0-1.4)	V1=1444 (440)	O/B	PERP. TO DYKE
			4.6-15.8(1.4-4.8)	V2=4333 (1321)	TILL	
			15.8-(4.8-)	V3=12082 (3683)	BEDROCK	
S15B	11+00	W TO E	0-4.9(0-1.5)	V1=1181 (360)	O/B	PERP. TO DYKE
			4.9-14.0(1.5-4.3)	V2=4333 (1321)	TILL	
			14.0-(4.3-)	V3=10800 (3292)	BEDROCK	
S16A	14+00	W TO E	0-4.9(0-1.5)	V1=1181 (360)	O/B	PERP. TO DYKE
			4.9-14.7(1.5-4.5)	V2=4333 (1321)	TILL	
			14.7-(4.5-)	V3=10604 (3232)	BEDROCK	

S16B	14+00	E TO W	0-4.7(0-1.4) 4.7-13.4(1.4-4.1) 13.4-(4.1-)	V1=1181 (360) V2=3714 (1132) V3=10947 (3337)	O/B TILL BEDROCK	PERP. TO DYKE
S17A	36+10	E TO W	0-4.7(0-1.4) 4.7-27.7(1.4-8.4) 27.7-(8.4-)	V1=1444 (440) V2=4580 (1396) V3=6667 (2032)	O/B TILL ?	BOTTOM OF DYKE
S17B	34+54	W TO E	0-4.1(0-1.2) 4.1-31.9(1.2-9.7) 31.9-(9.7-)	V1=1466 (447) V2=4396 (1340) V3=6536 (1992)	O/B TILL ?	BOTTOM OF DYKE
S18A	34+50	E TO W	0-4.8(0-1.5) 4.8-29.8(1.5-9.1) 29.8-(9.1-)	V1=1300 (396) V2=4333 (1321) V3=7229 (2264)	O/B TILL ?	BOTTOM OF DYKE
S18B	32+94	W TO E	0-4.4(0-1.3) 4.4-28.1(1.3-8.5) 28.1-(8.5-)	V1=1700 (396) V2=4333 (1321) V3=6667 (2032)	O/B TILL ?	BOTTOM OF DYKE

APPENDIX A

DECEW GS - SEISMIC TESTING



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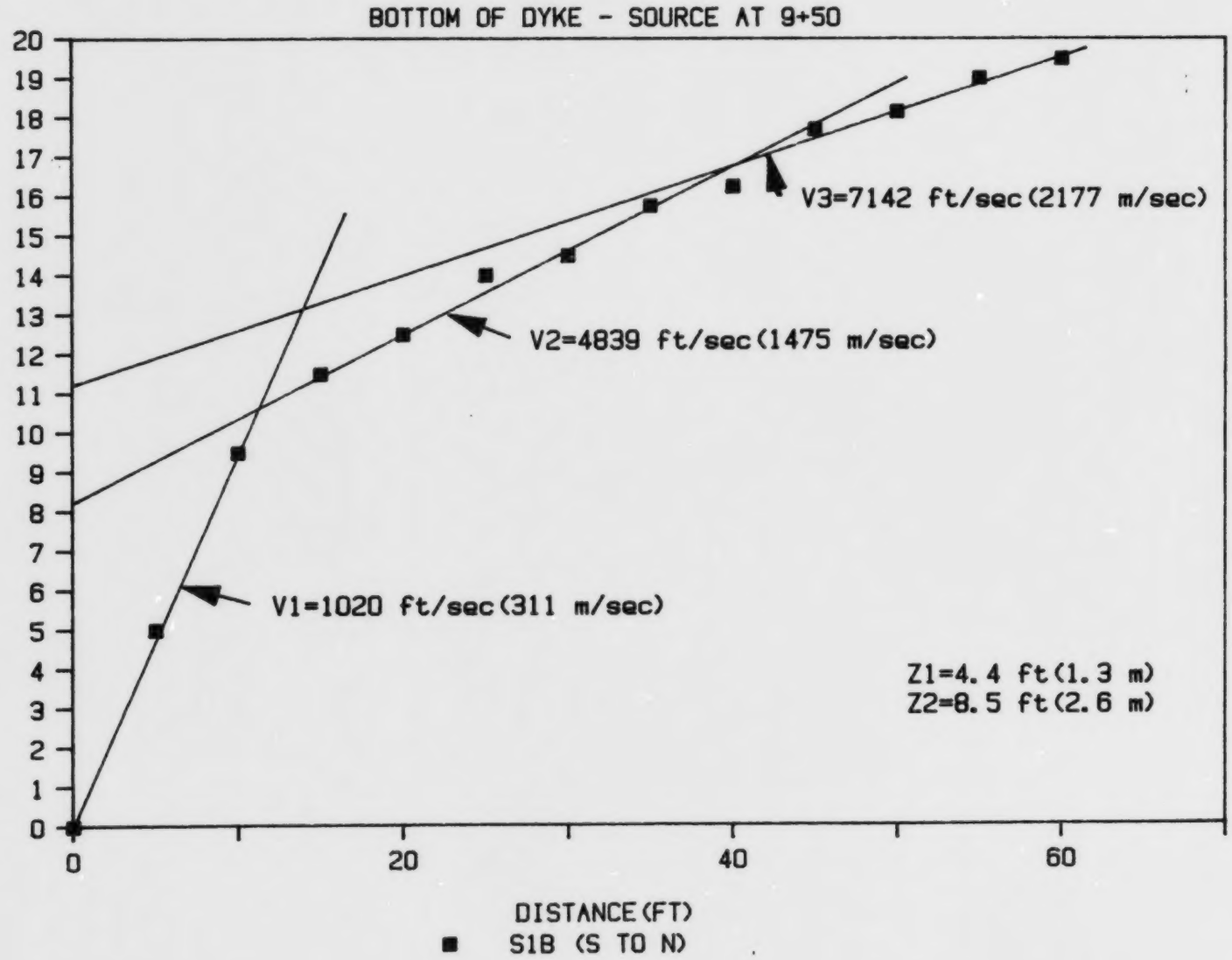

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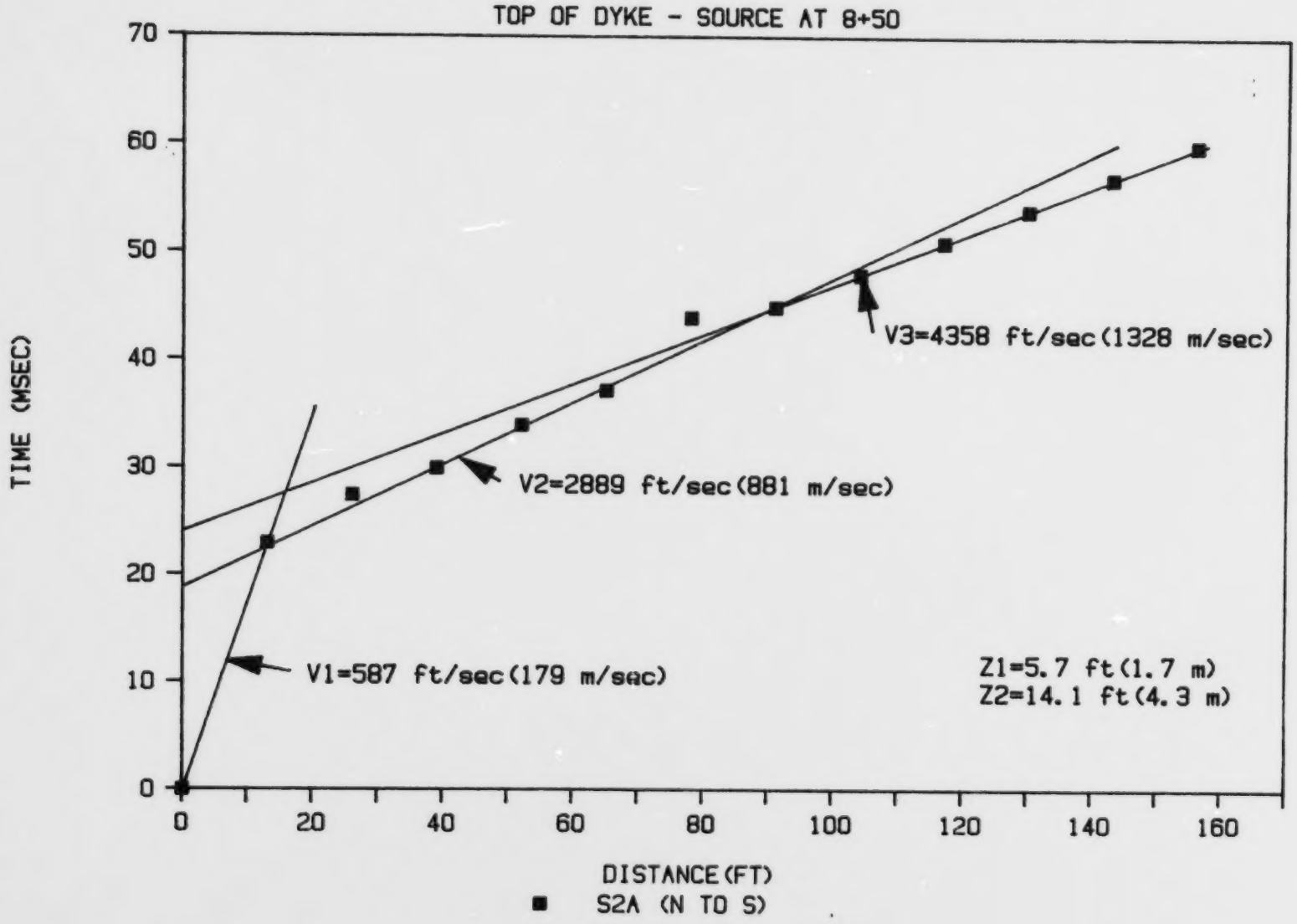

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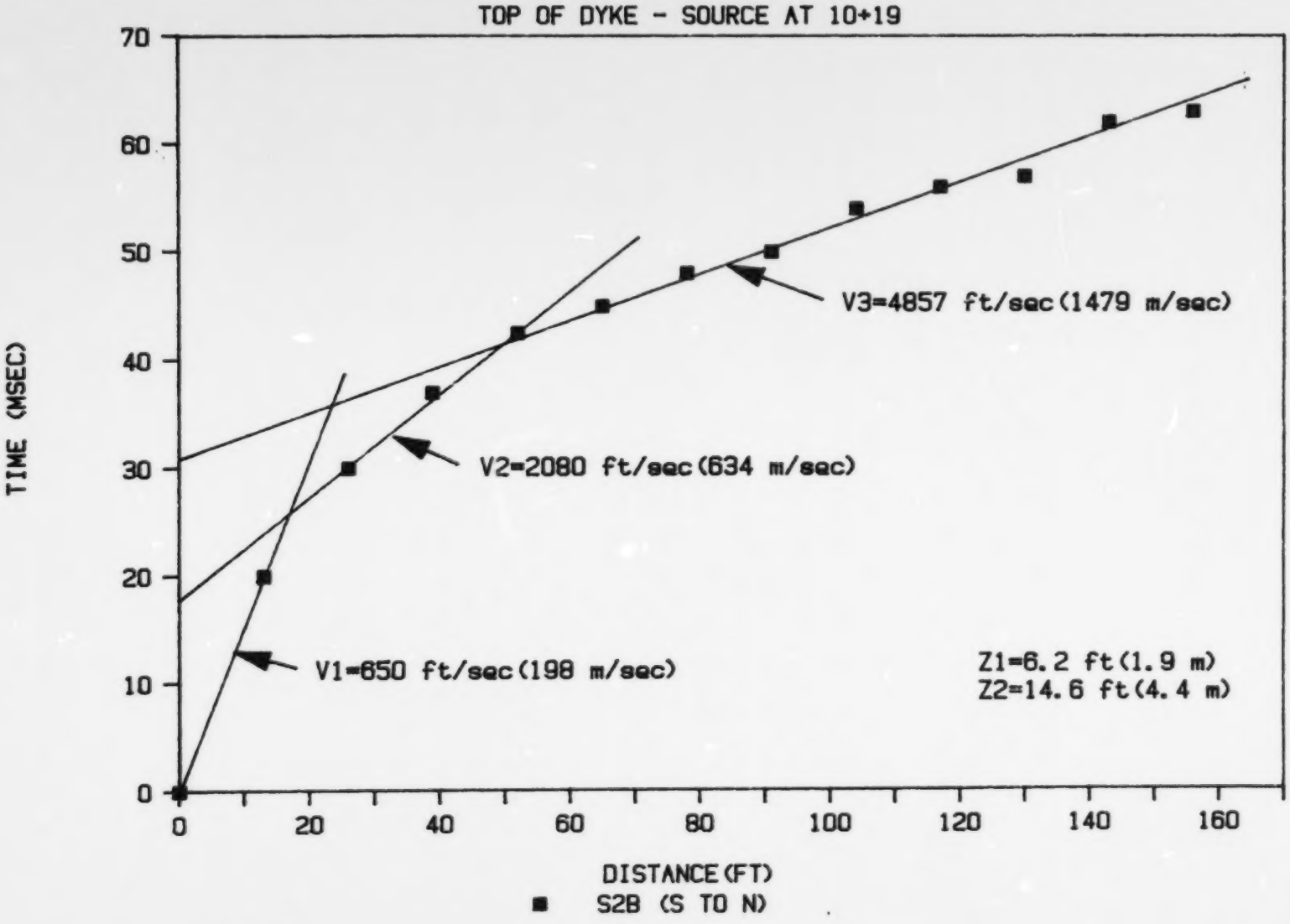

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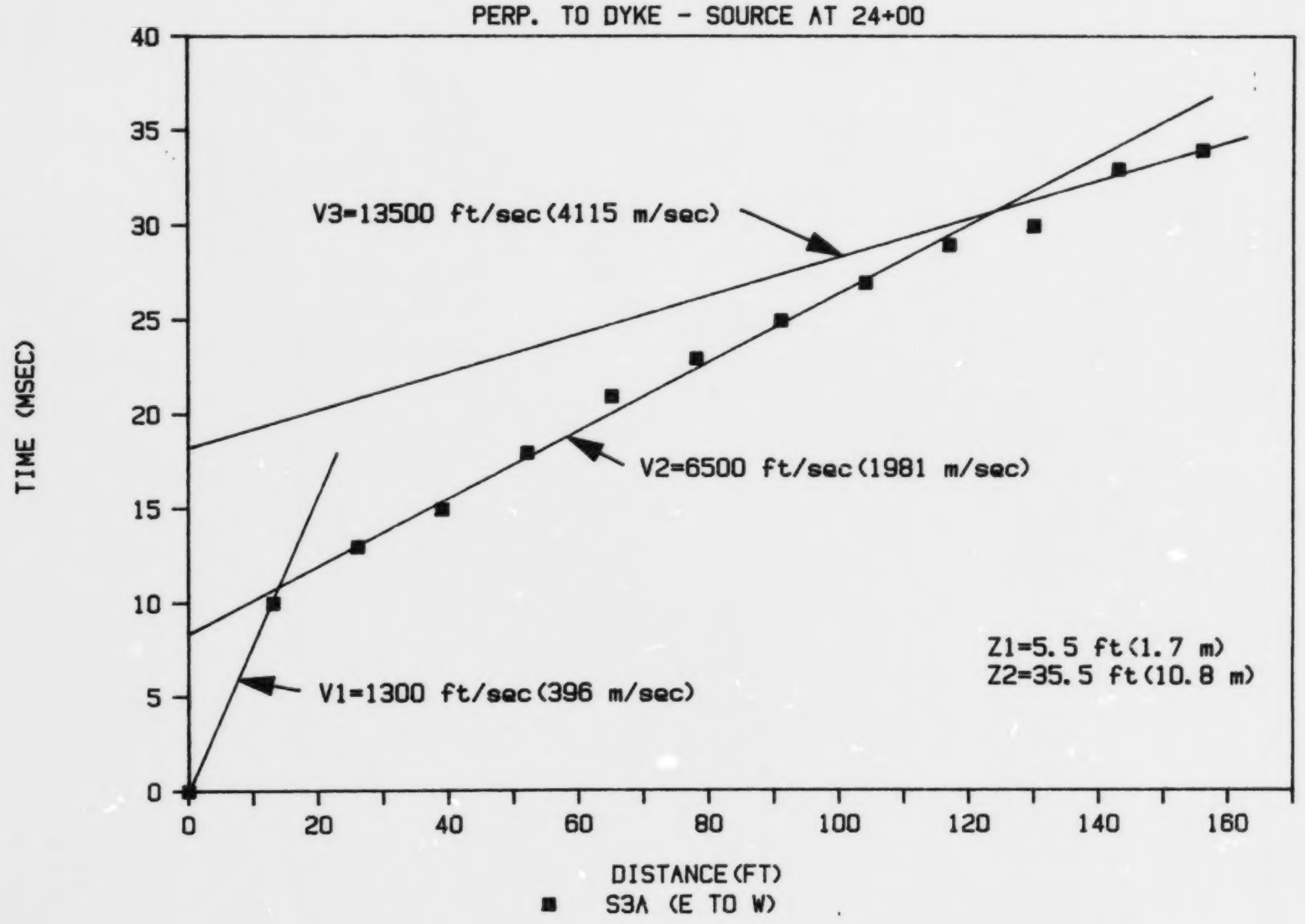

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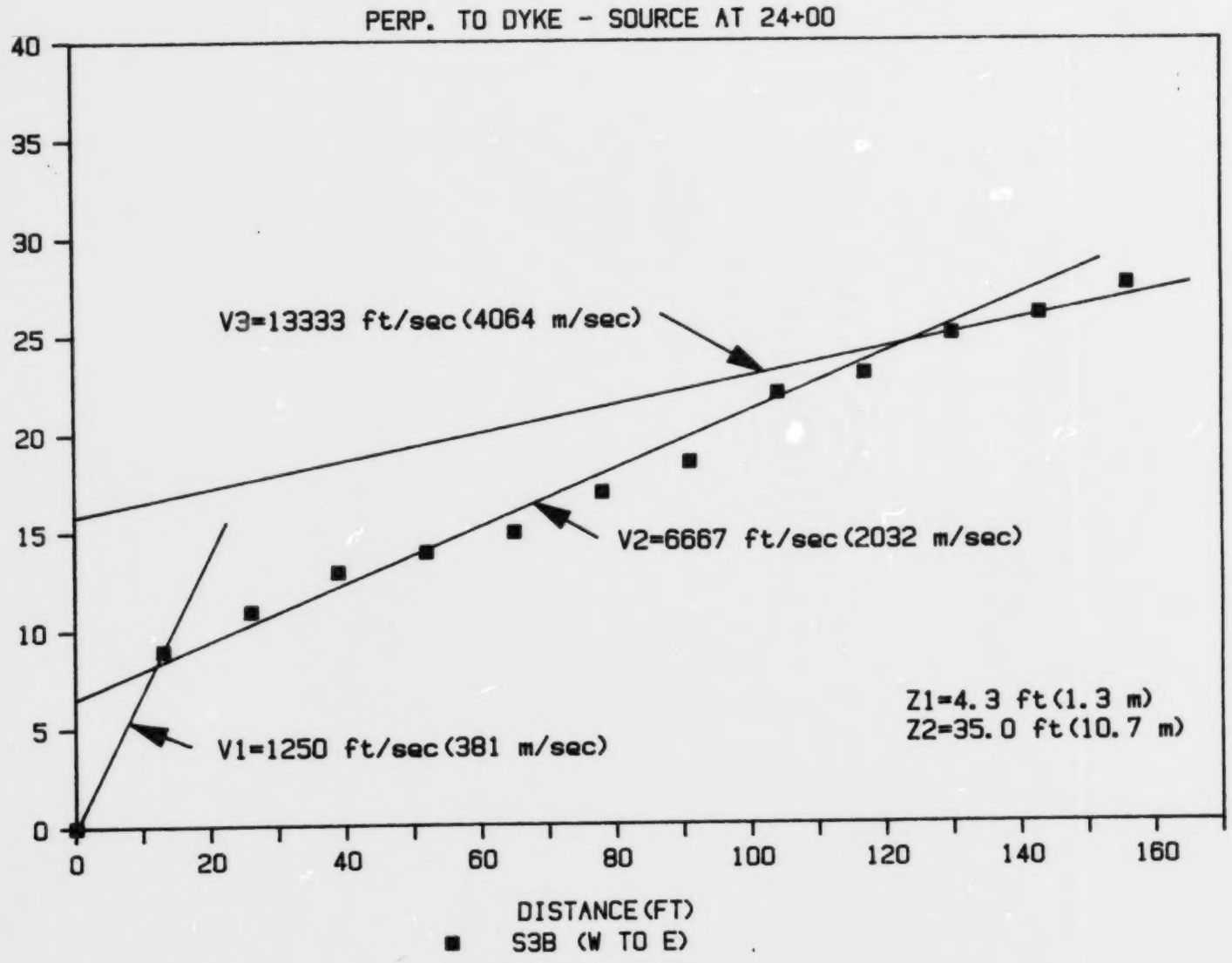

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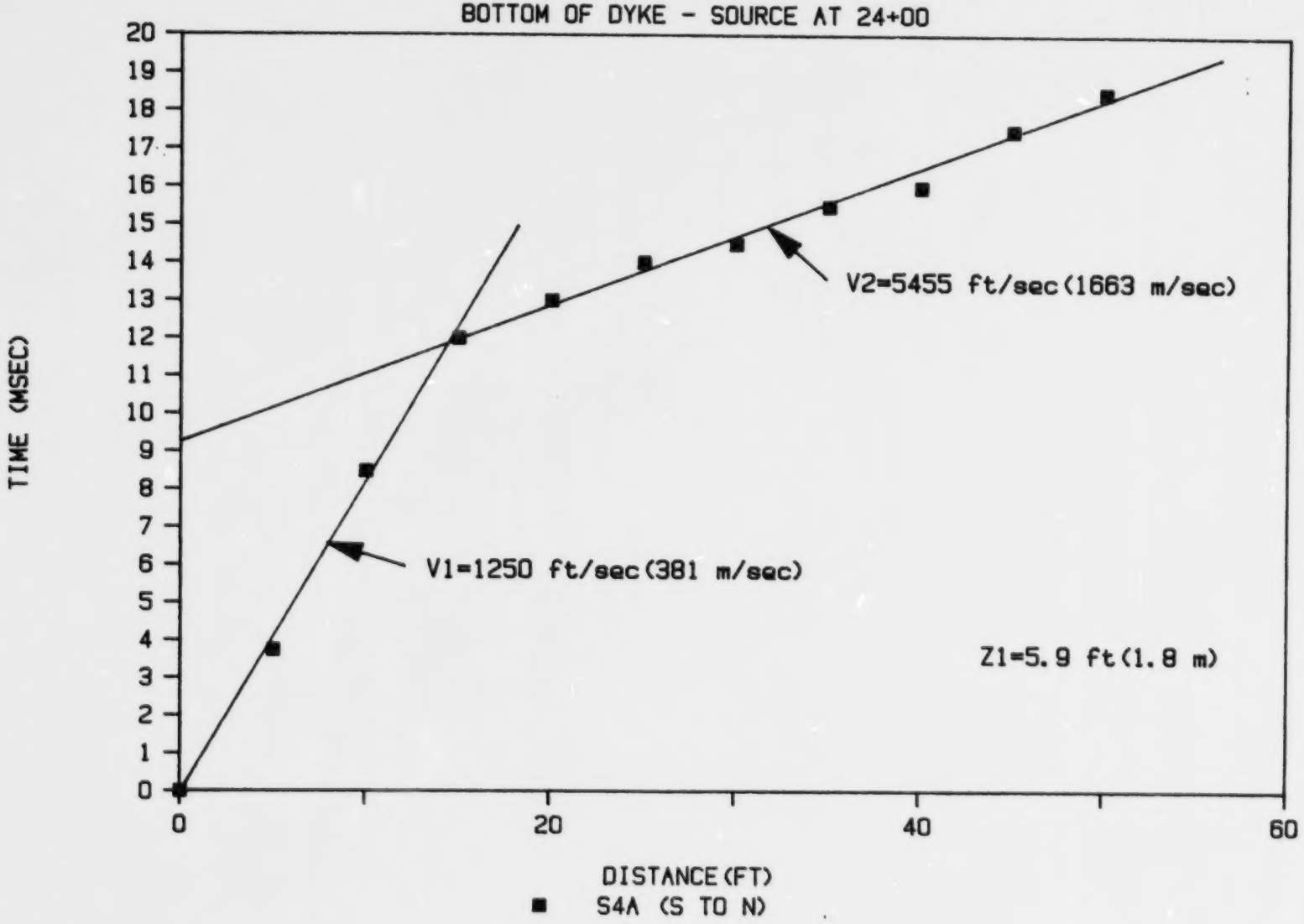

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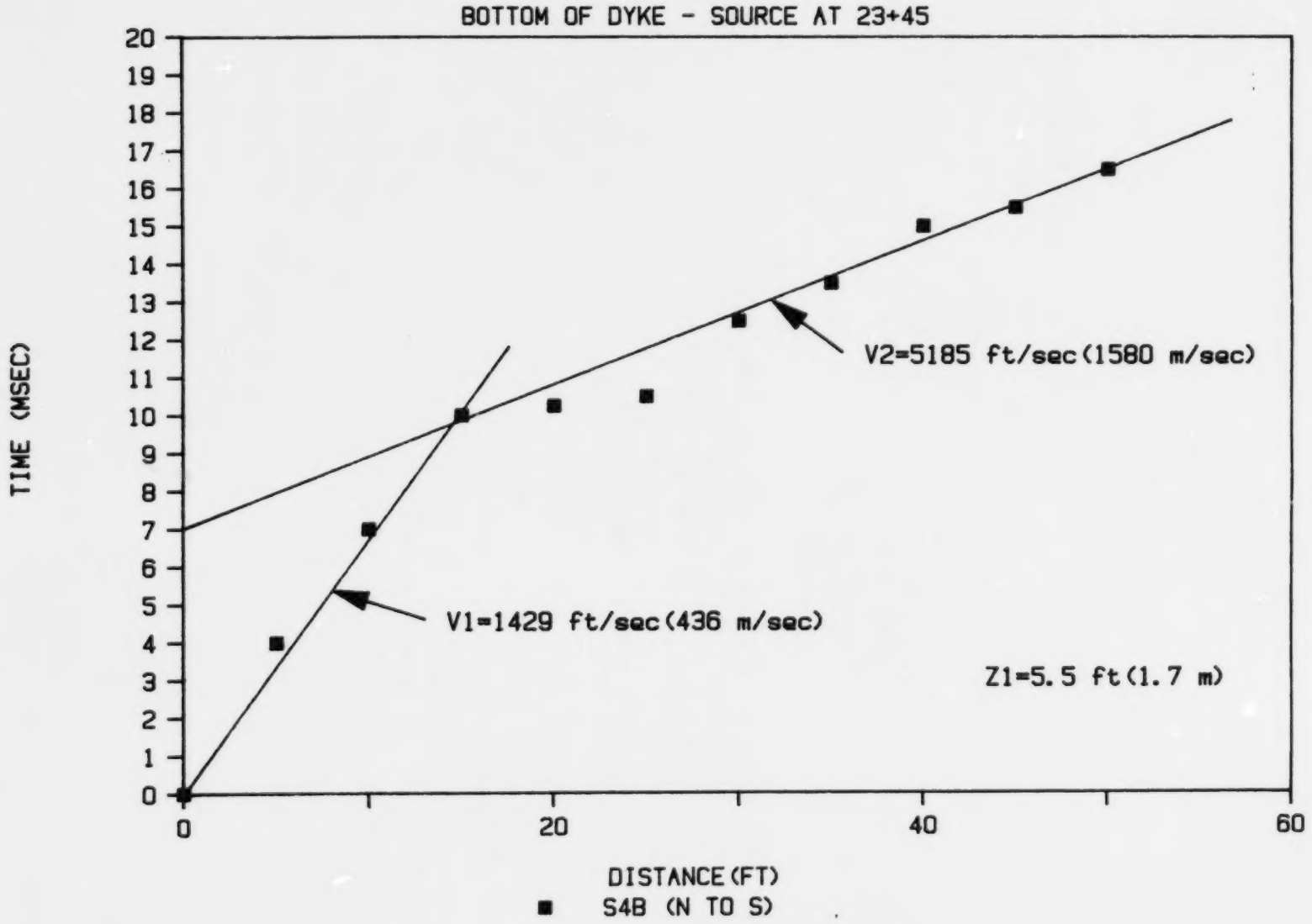

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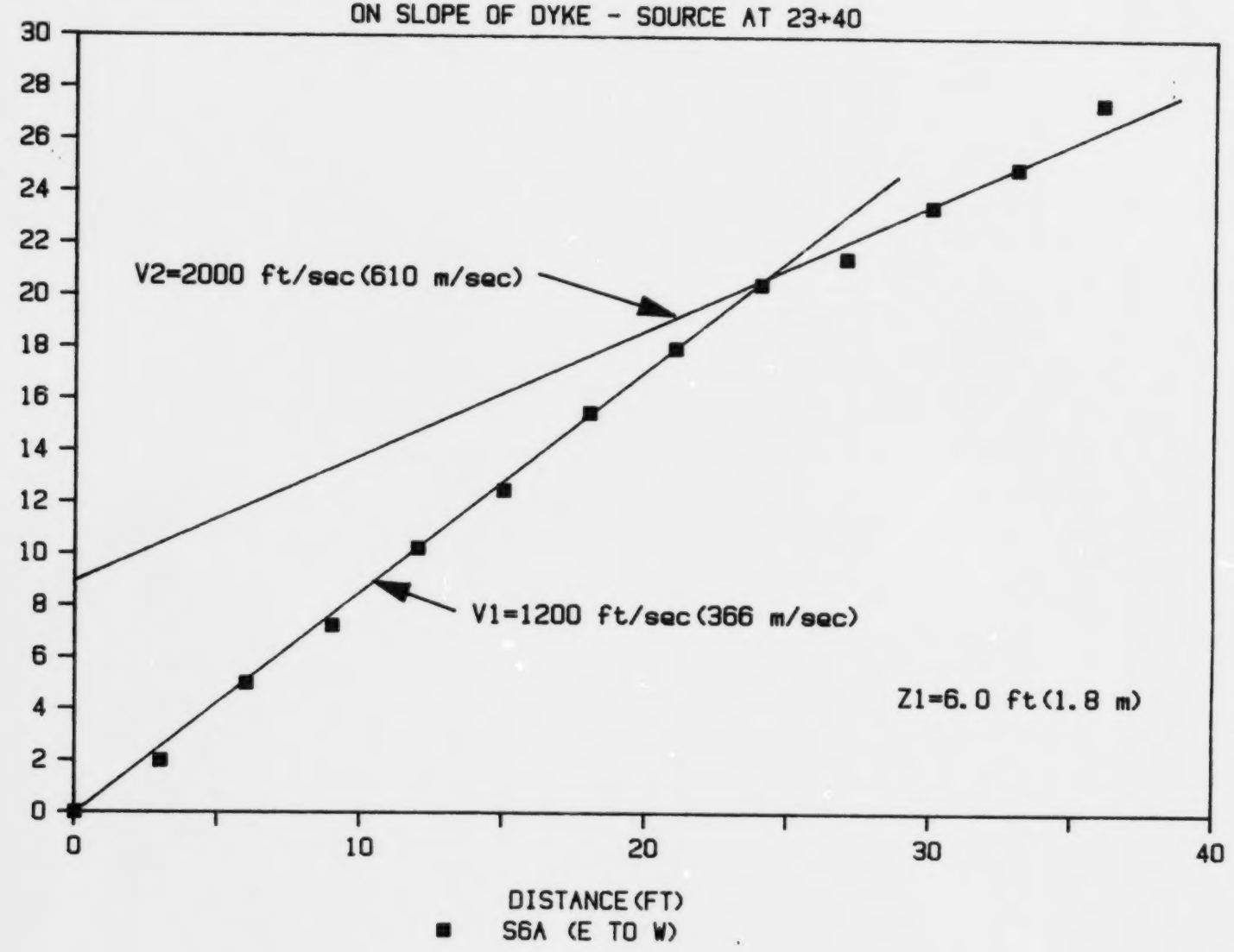

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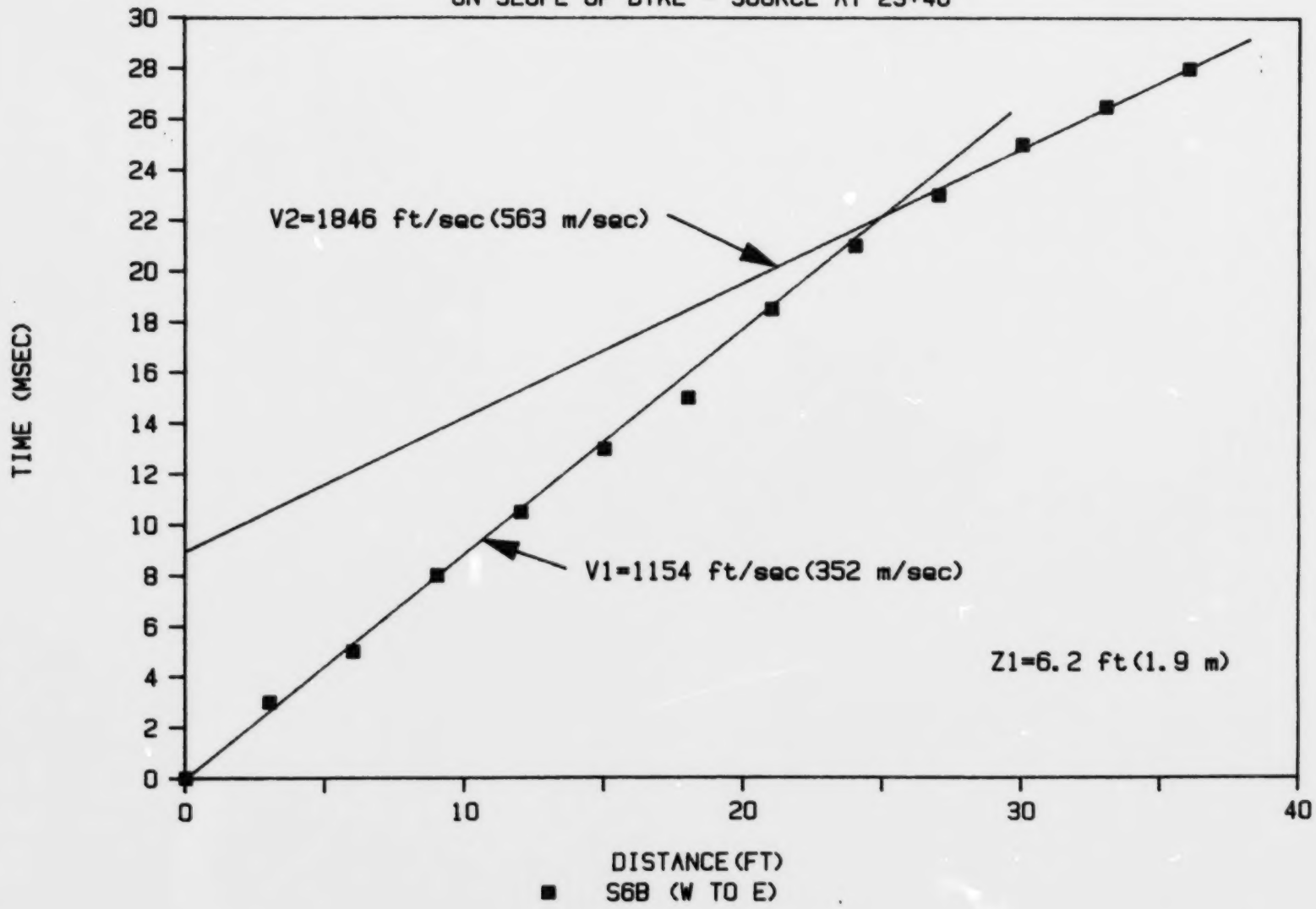

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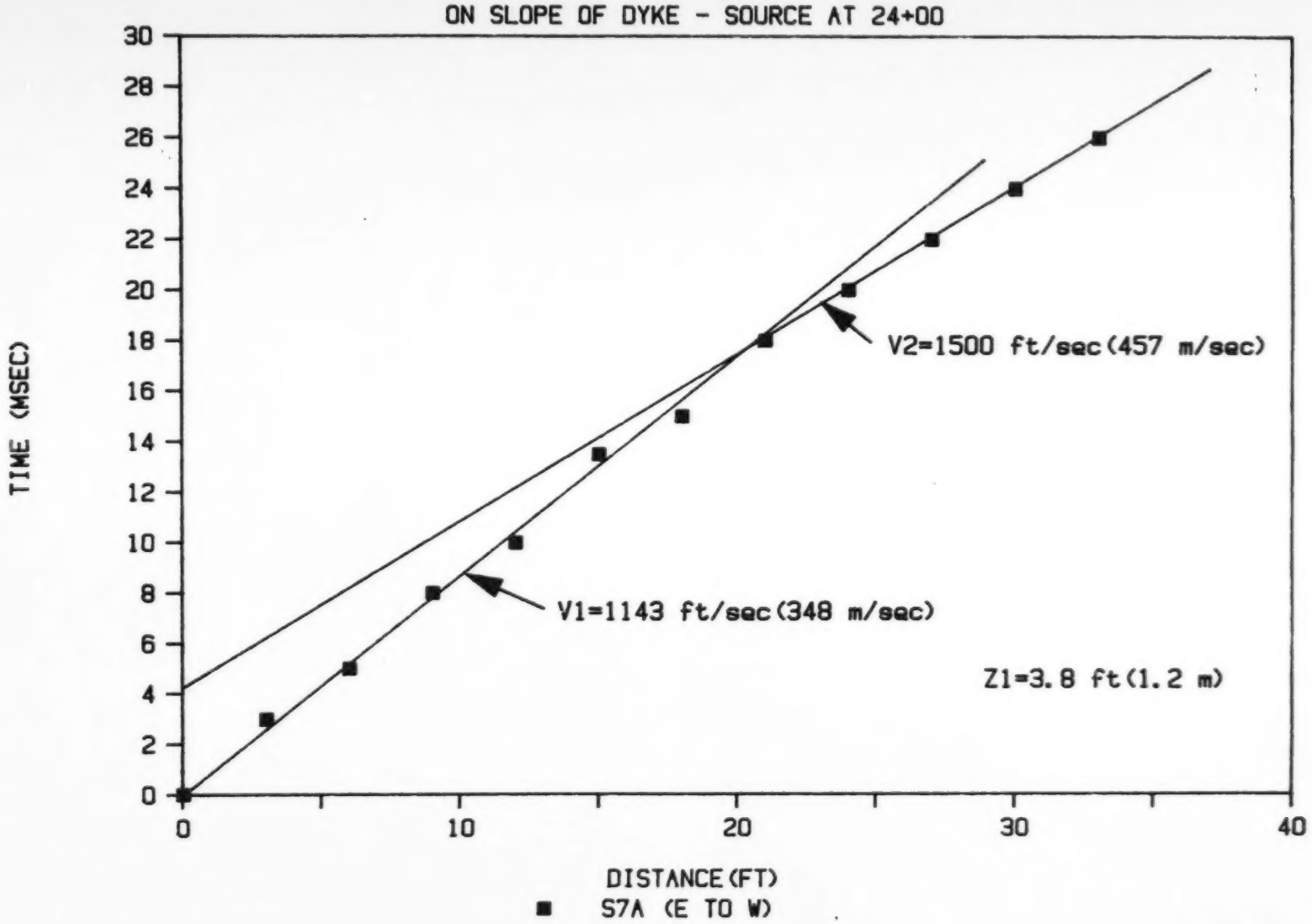

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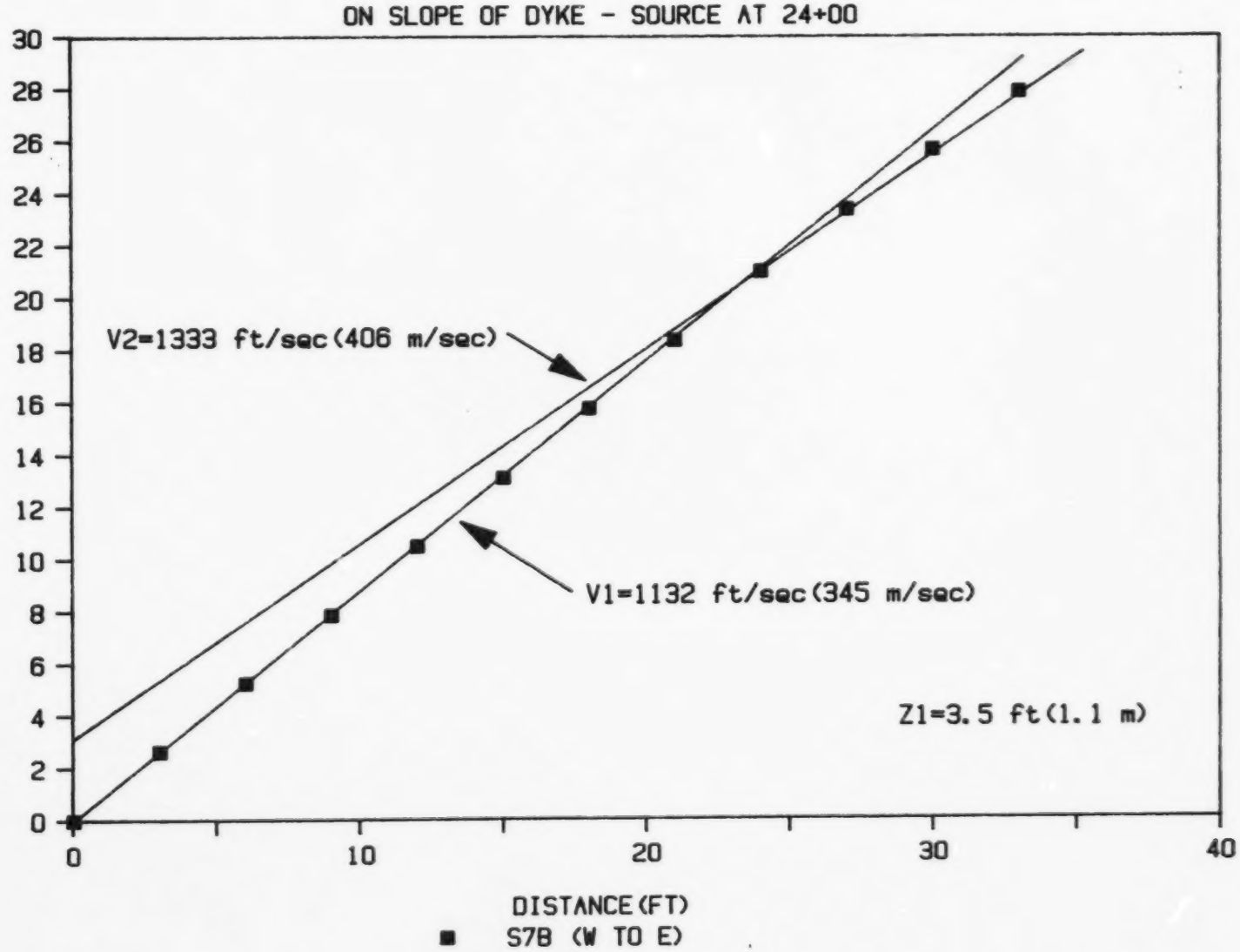

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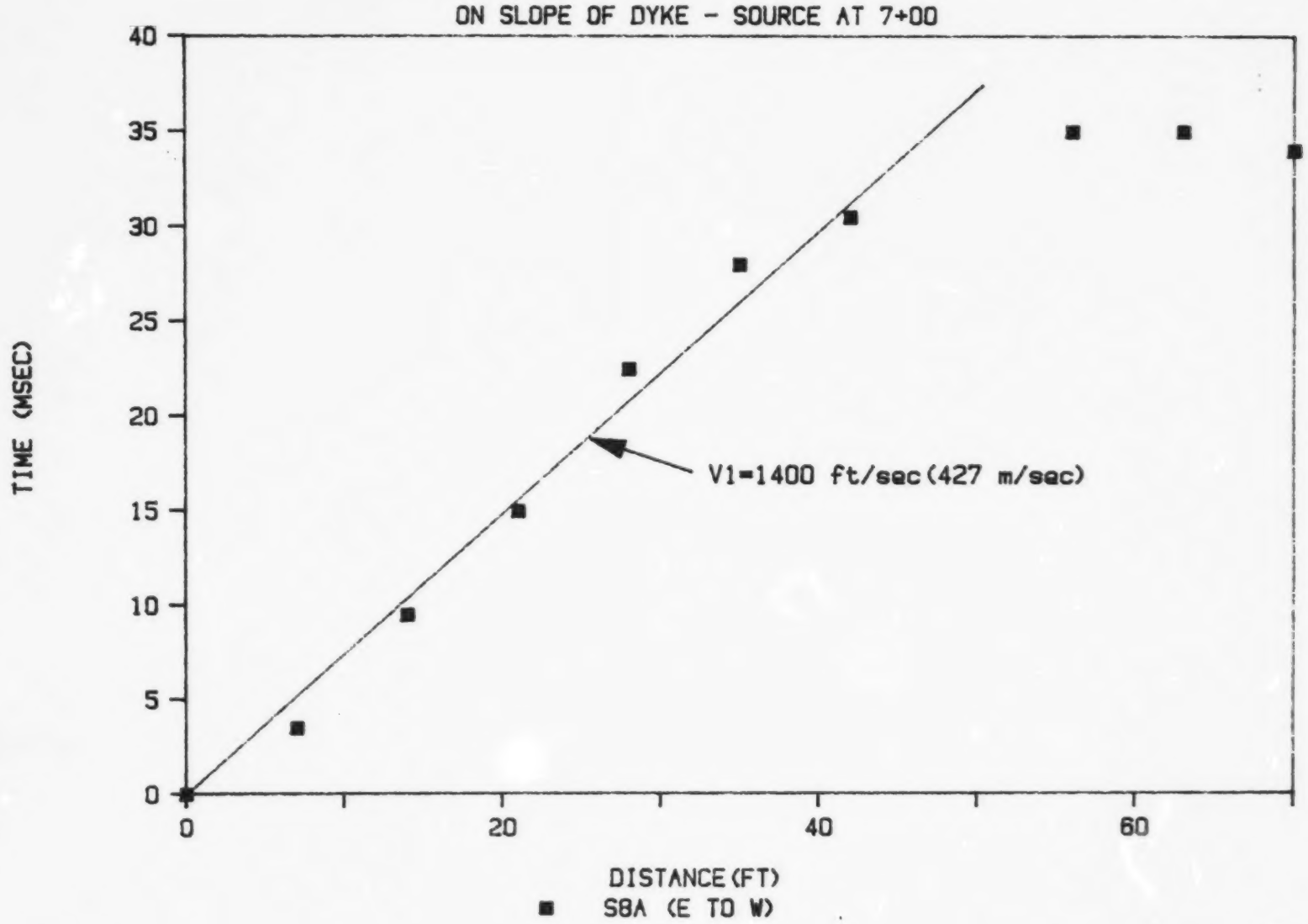

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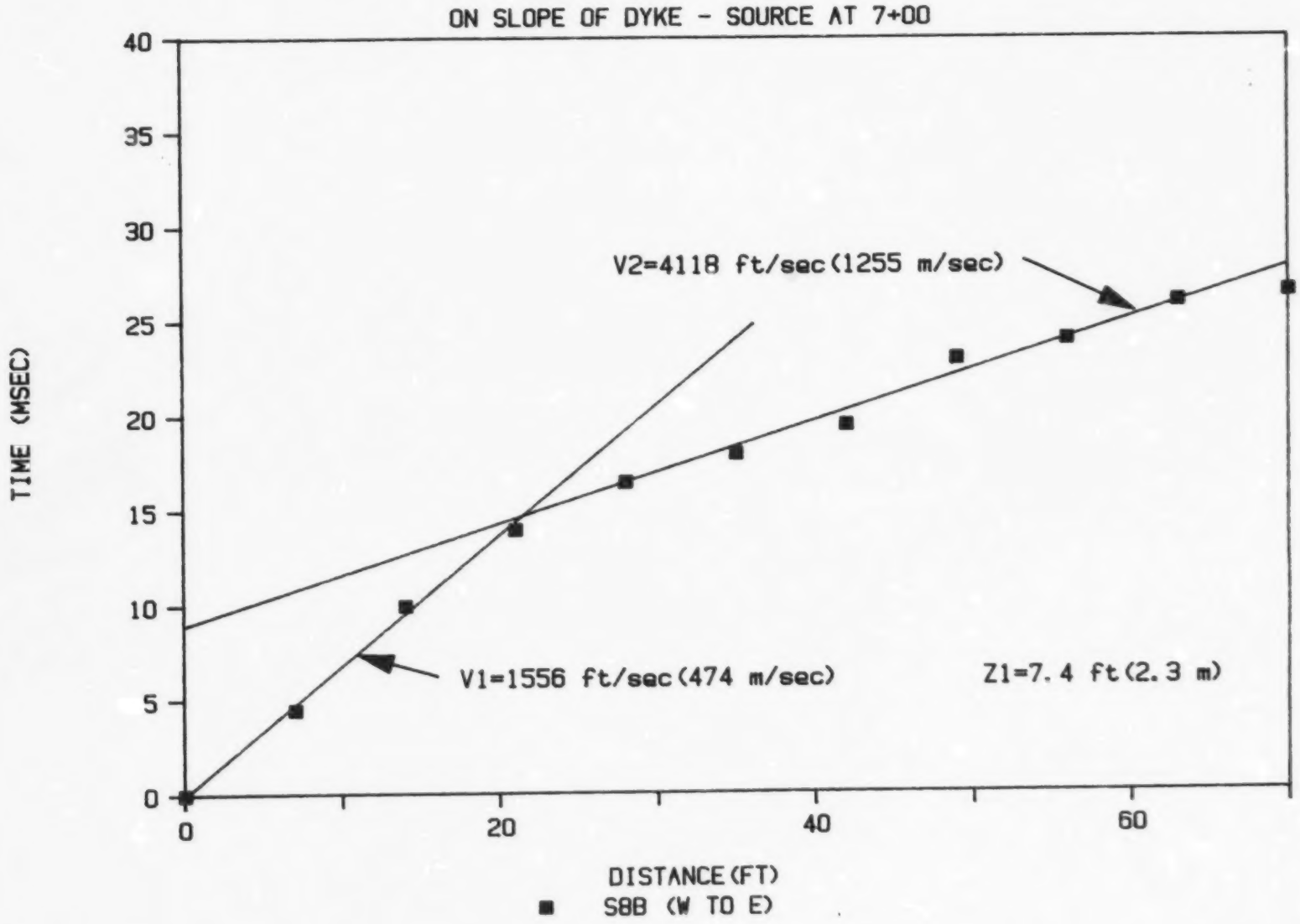
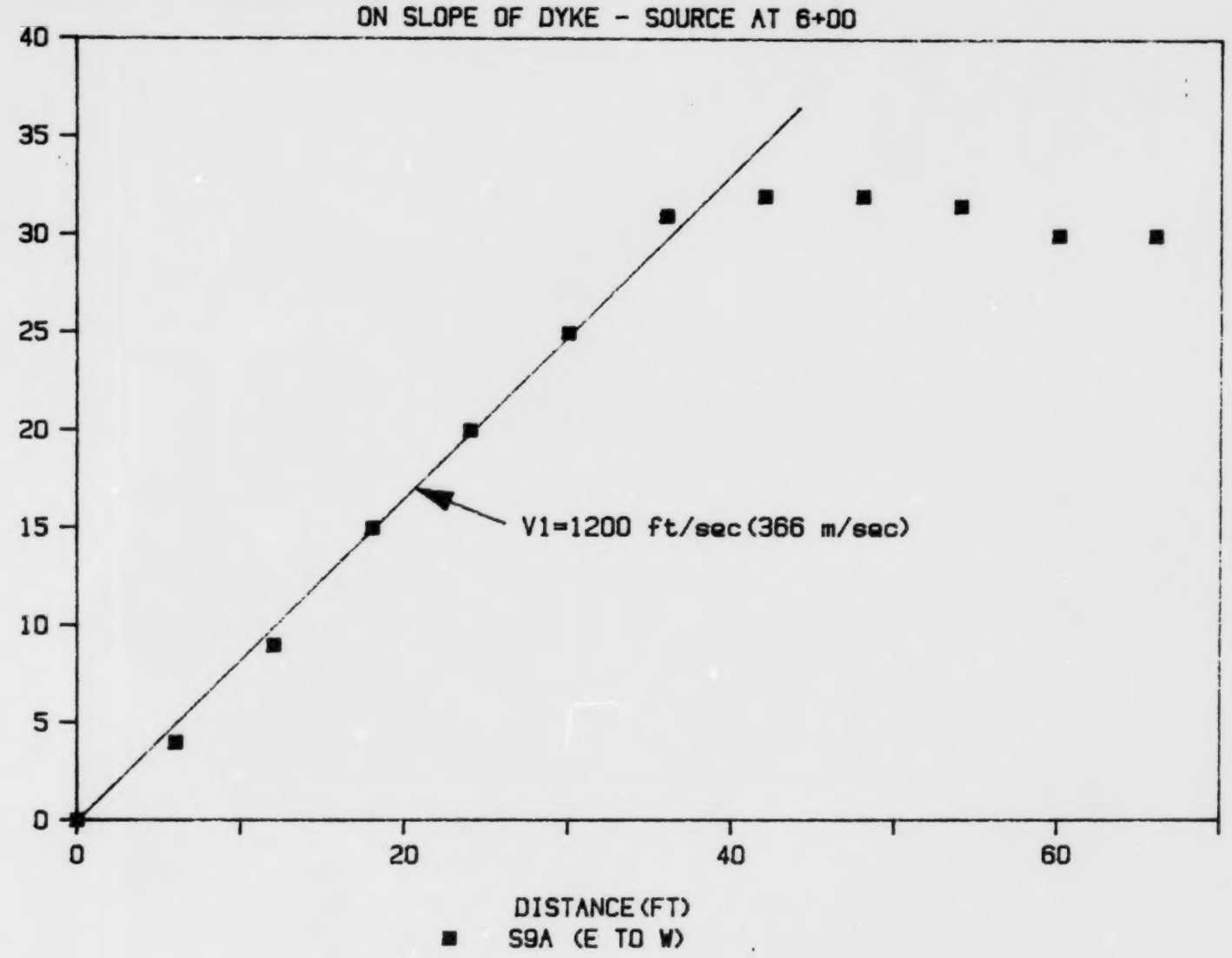
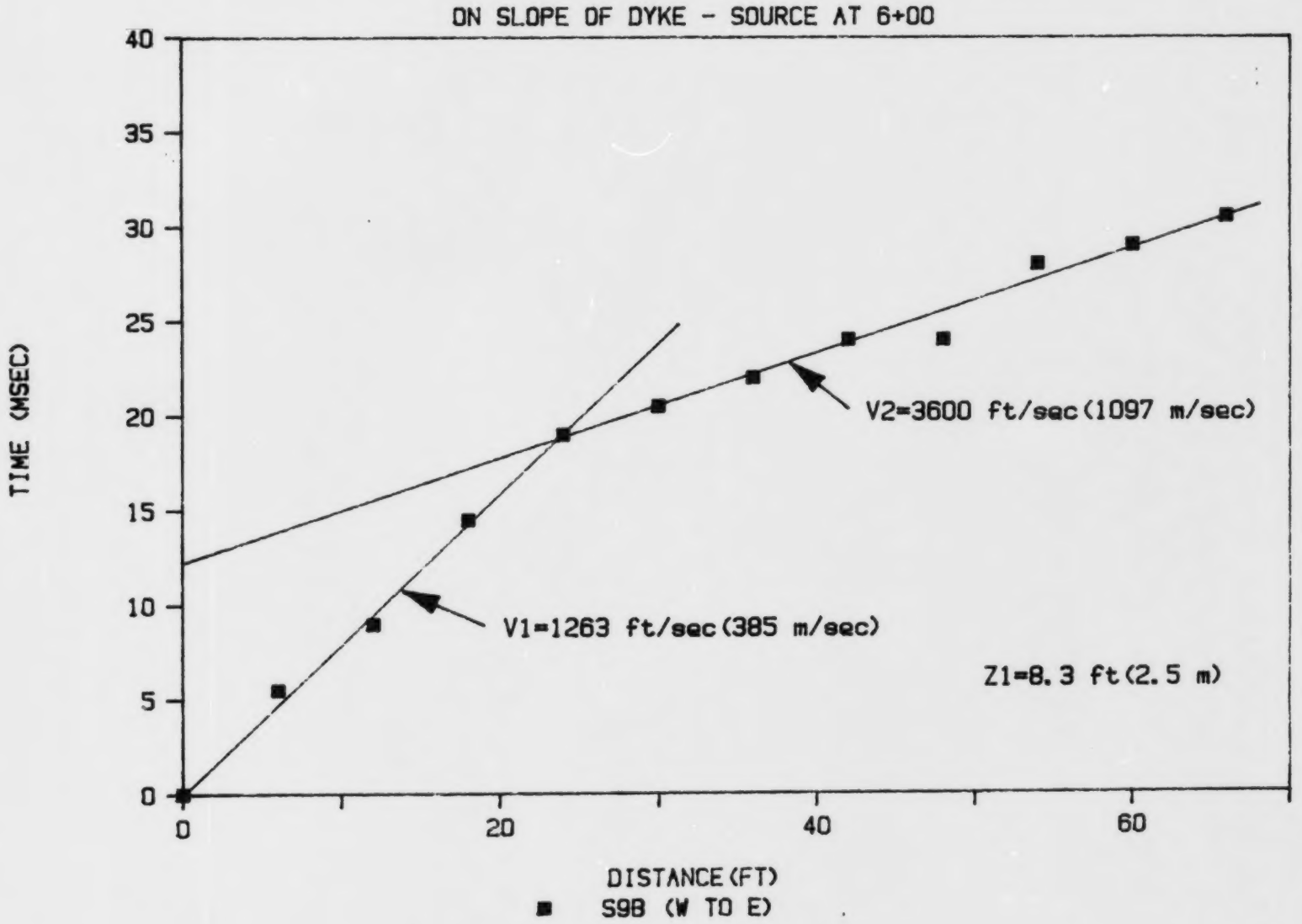


DECEW GS - SEISMIC TESTING



DECEW GS - SEISMIC TESTING



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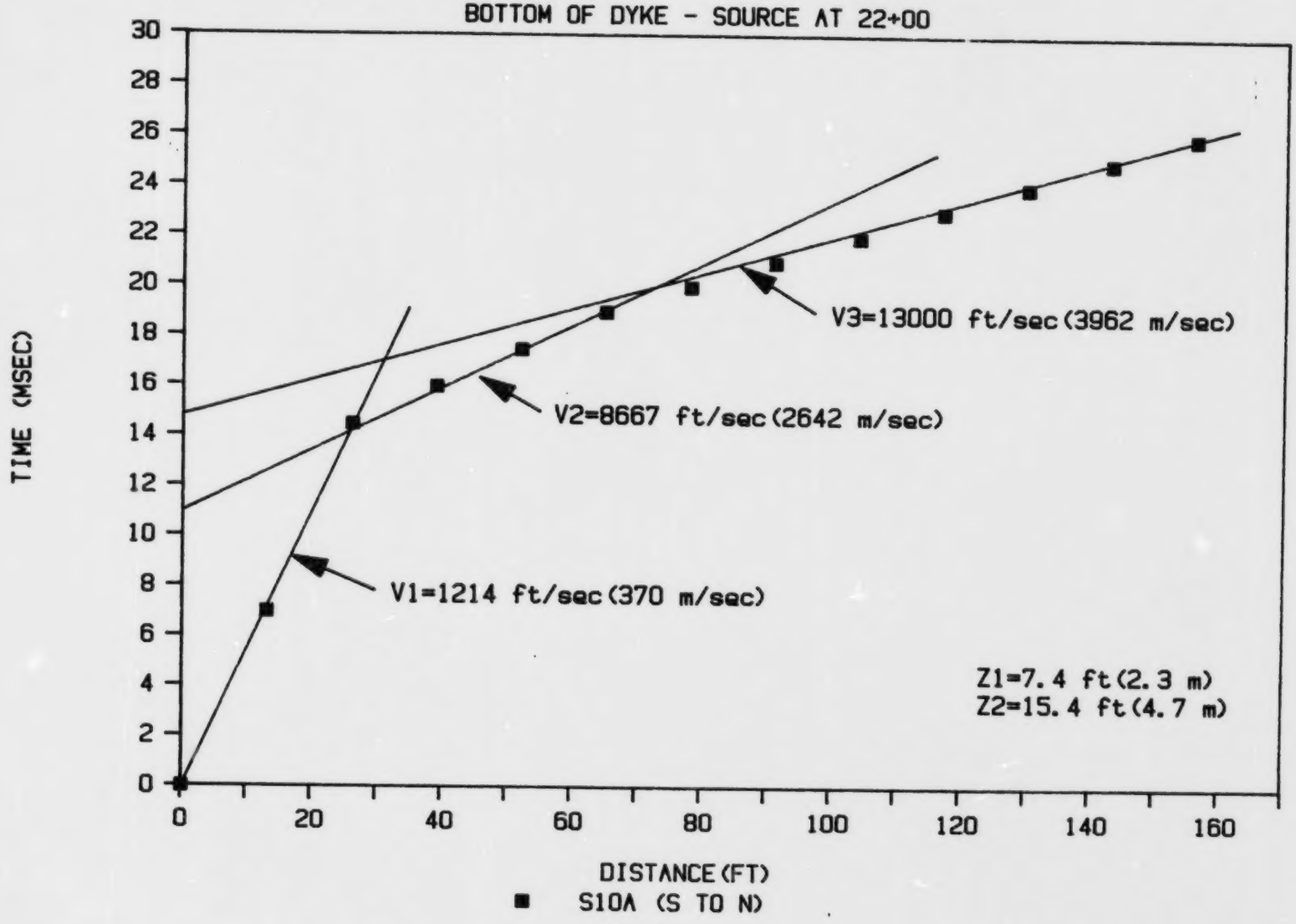

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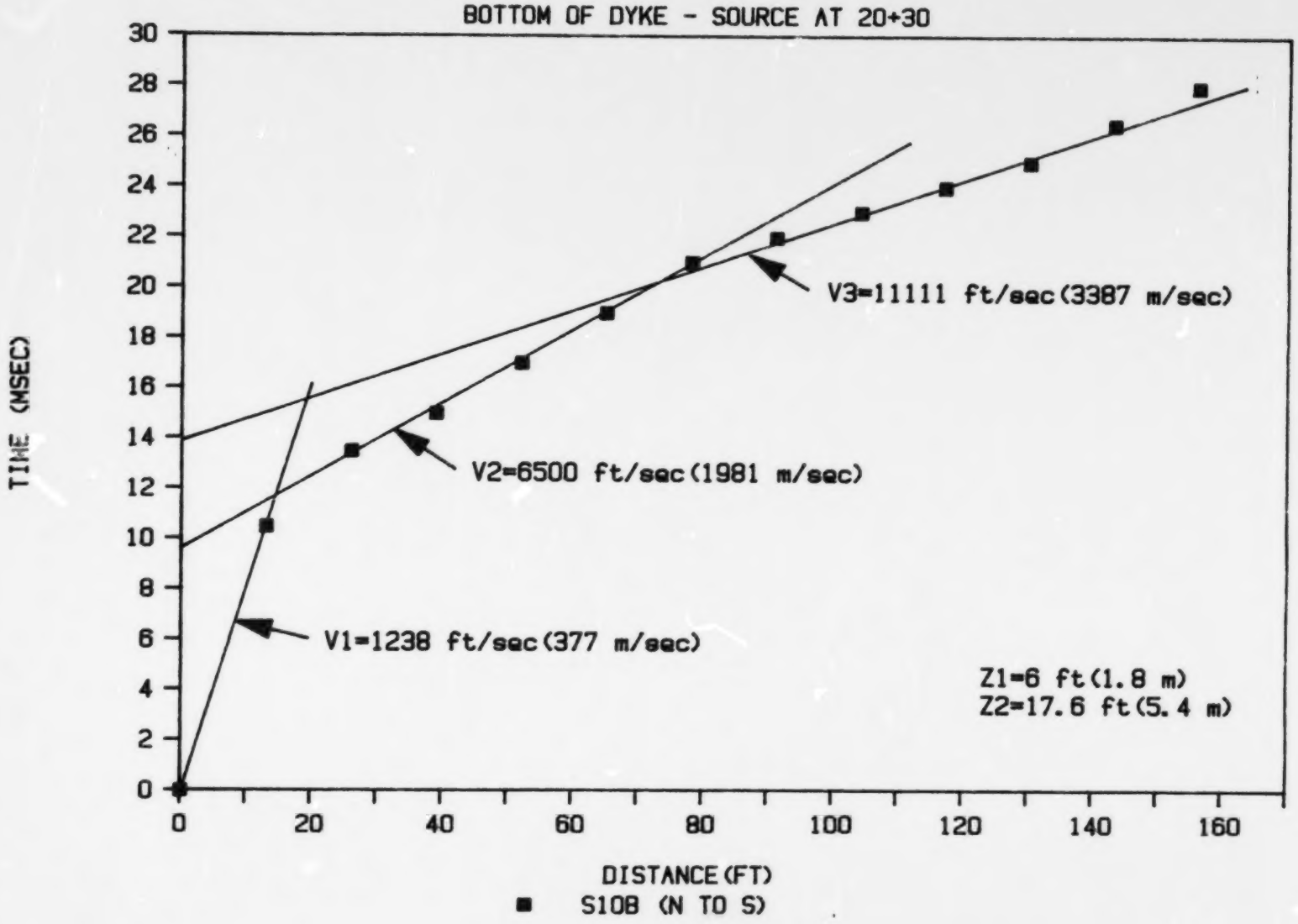

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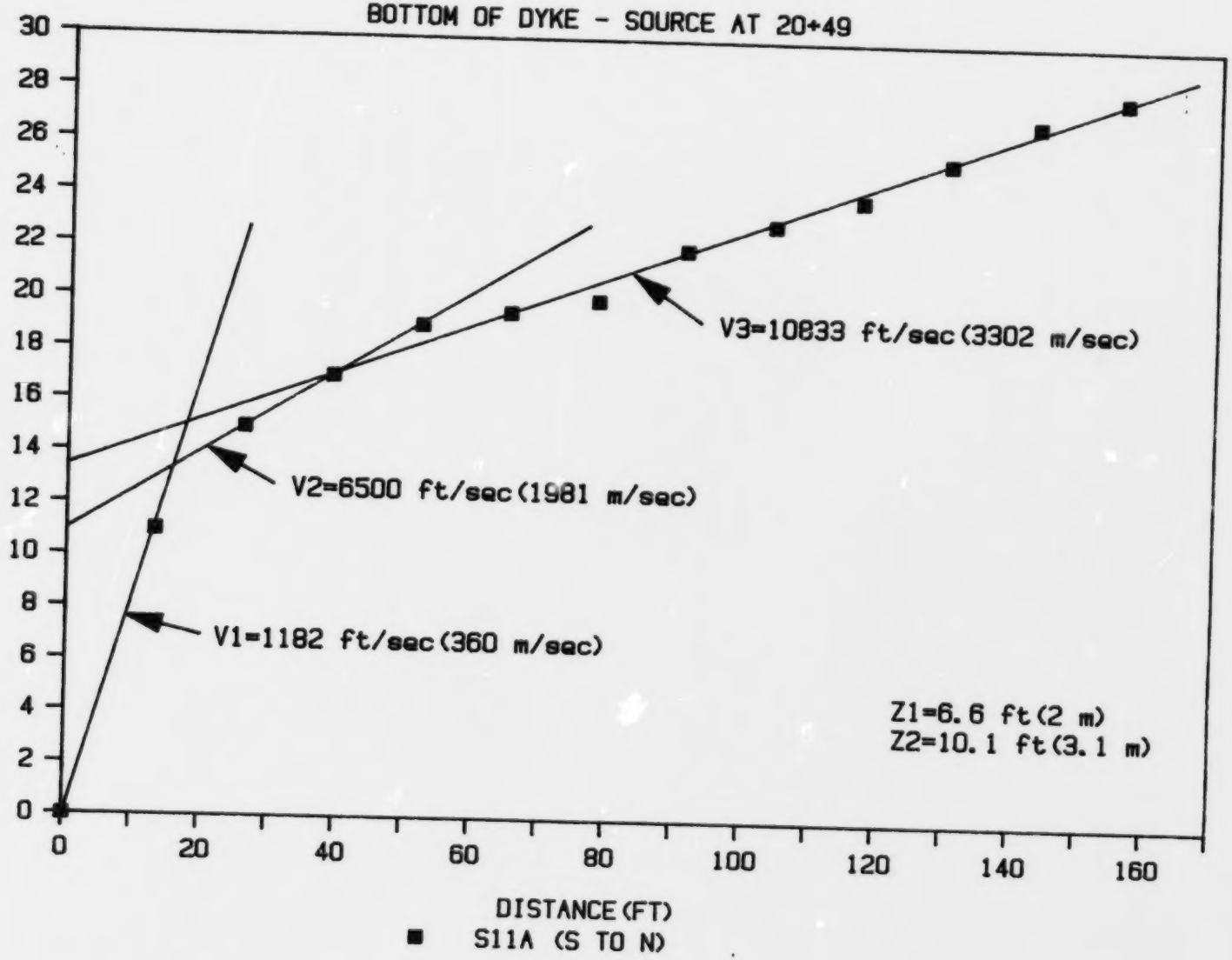
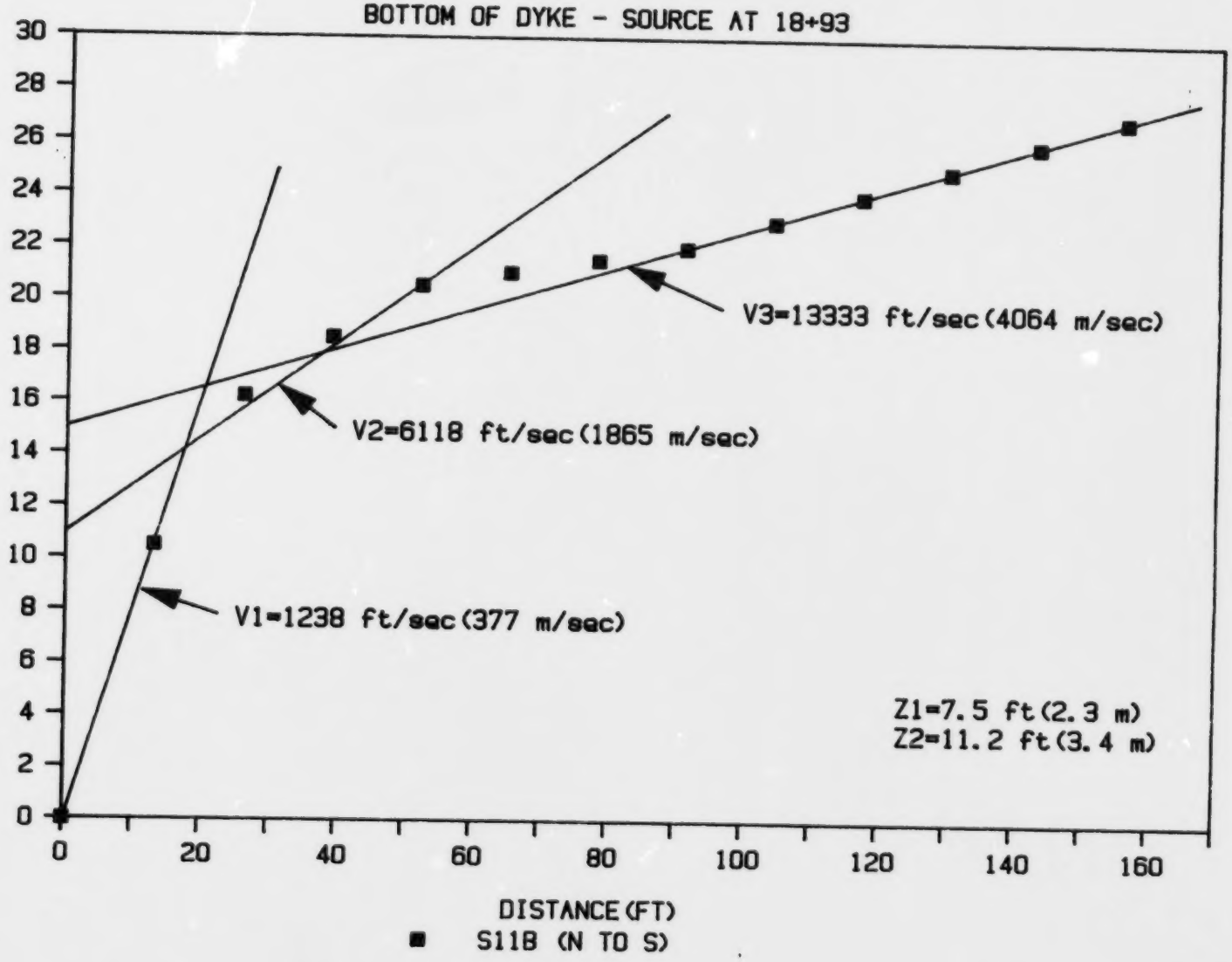
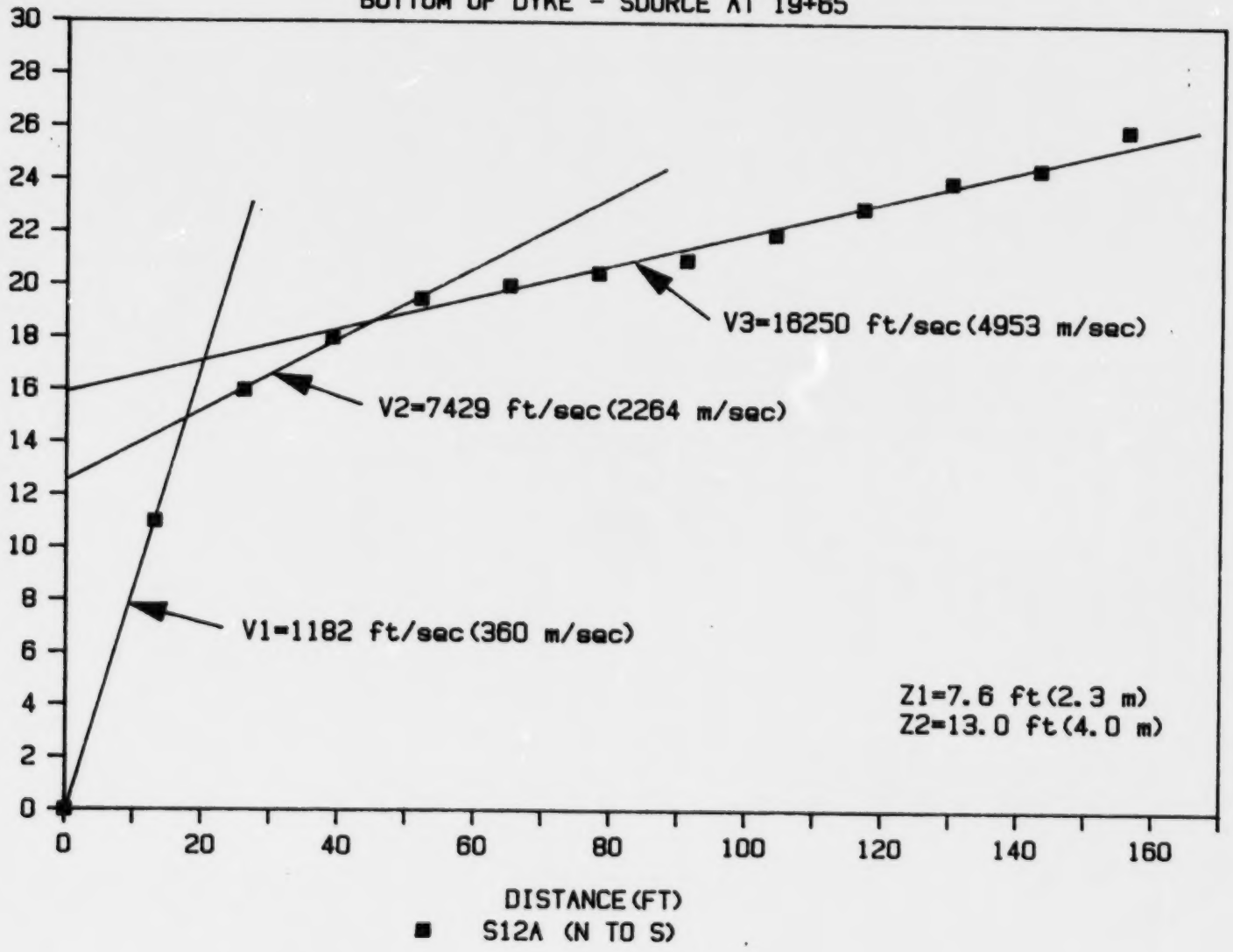


DECEW GS - SEISMIC TESTING



DECEW GS - SEISMIC TESTING



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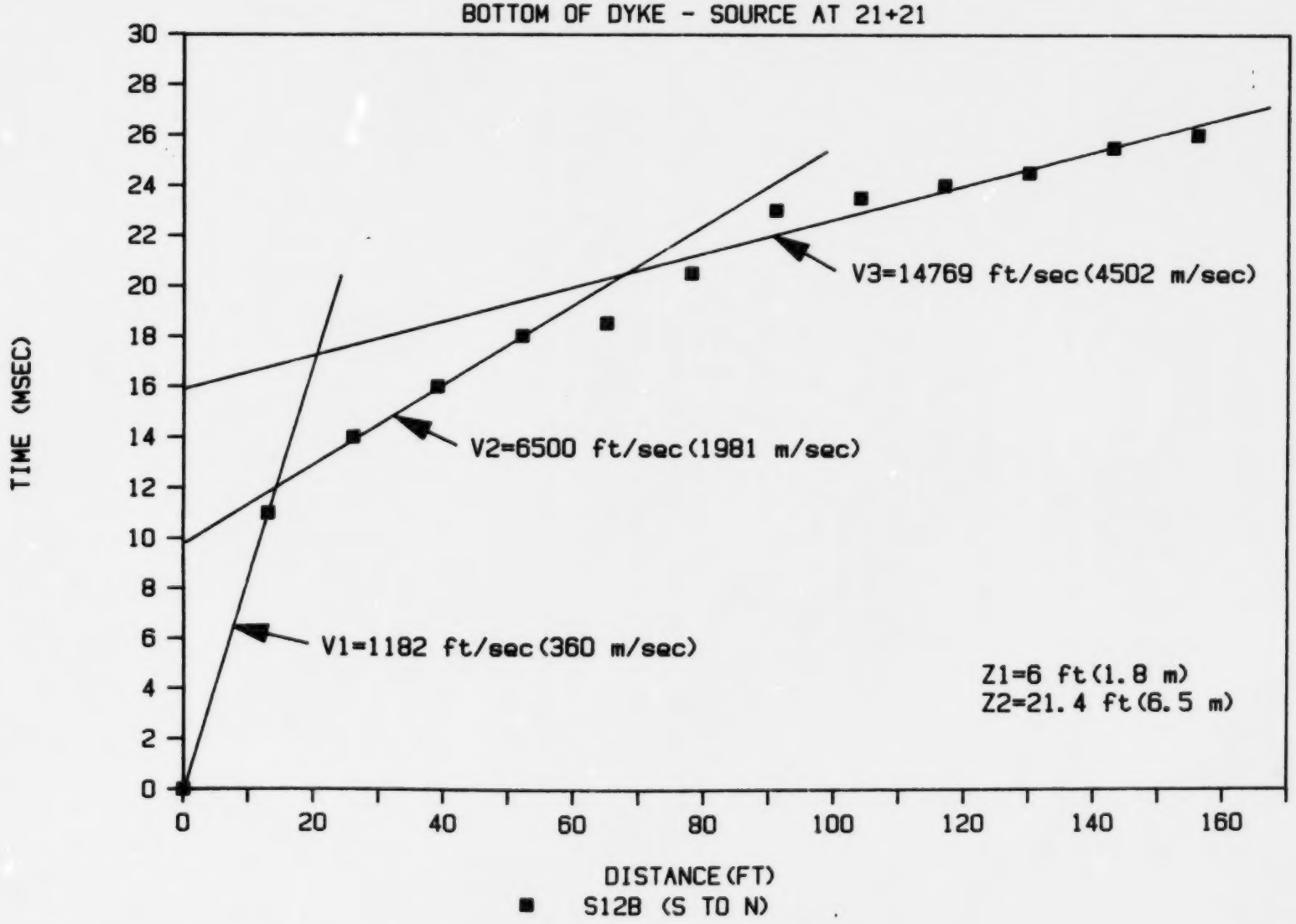
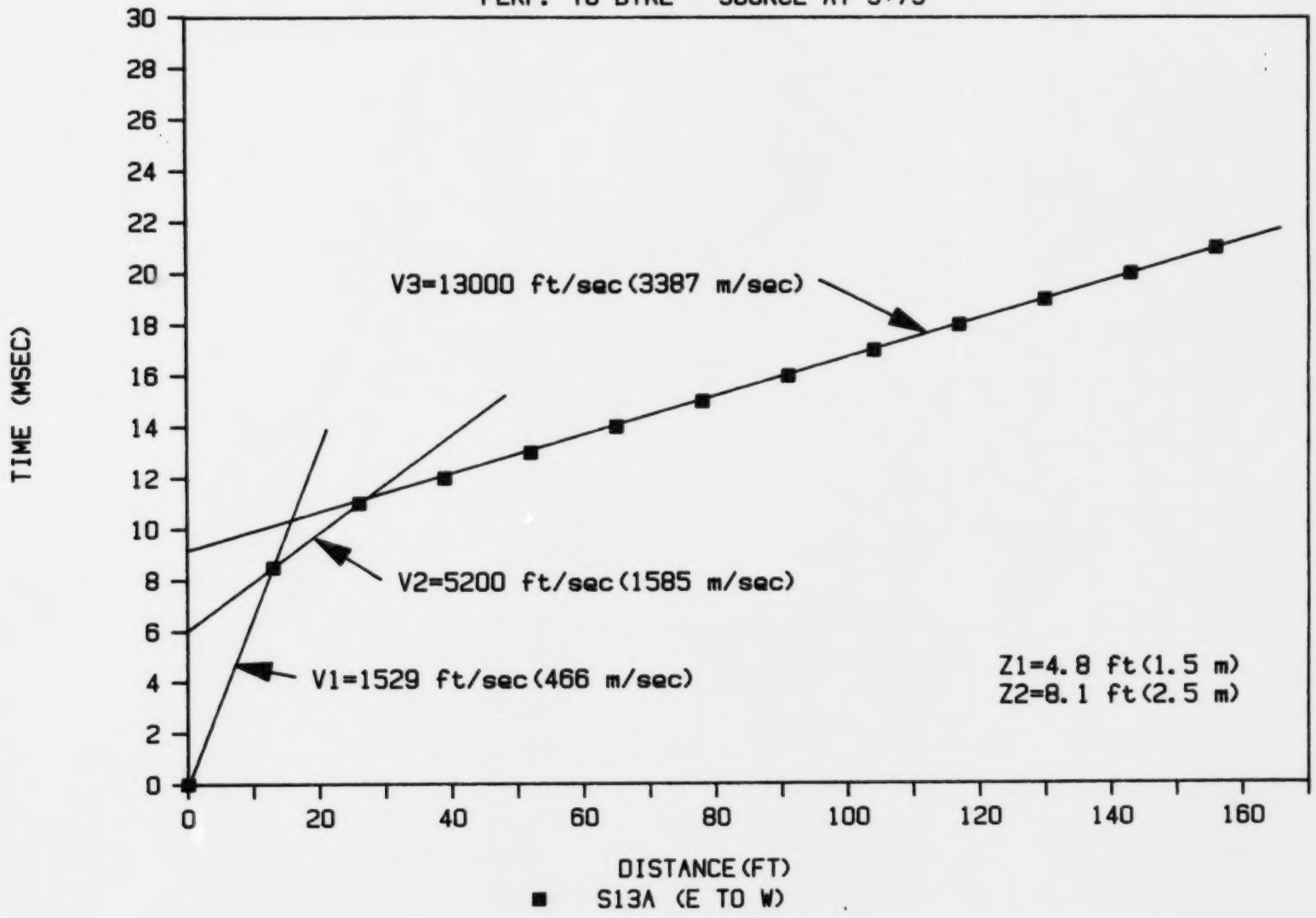


DECEW GS - SEISMIC TESTING



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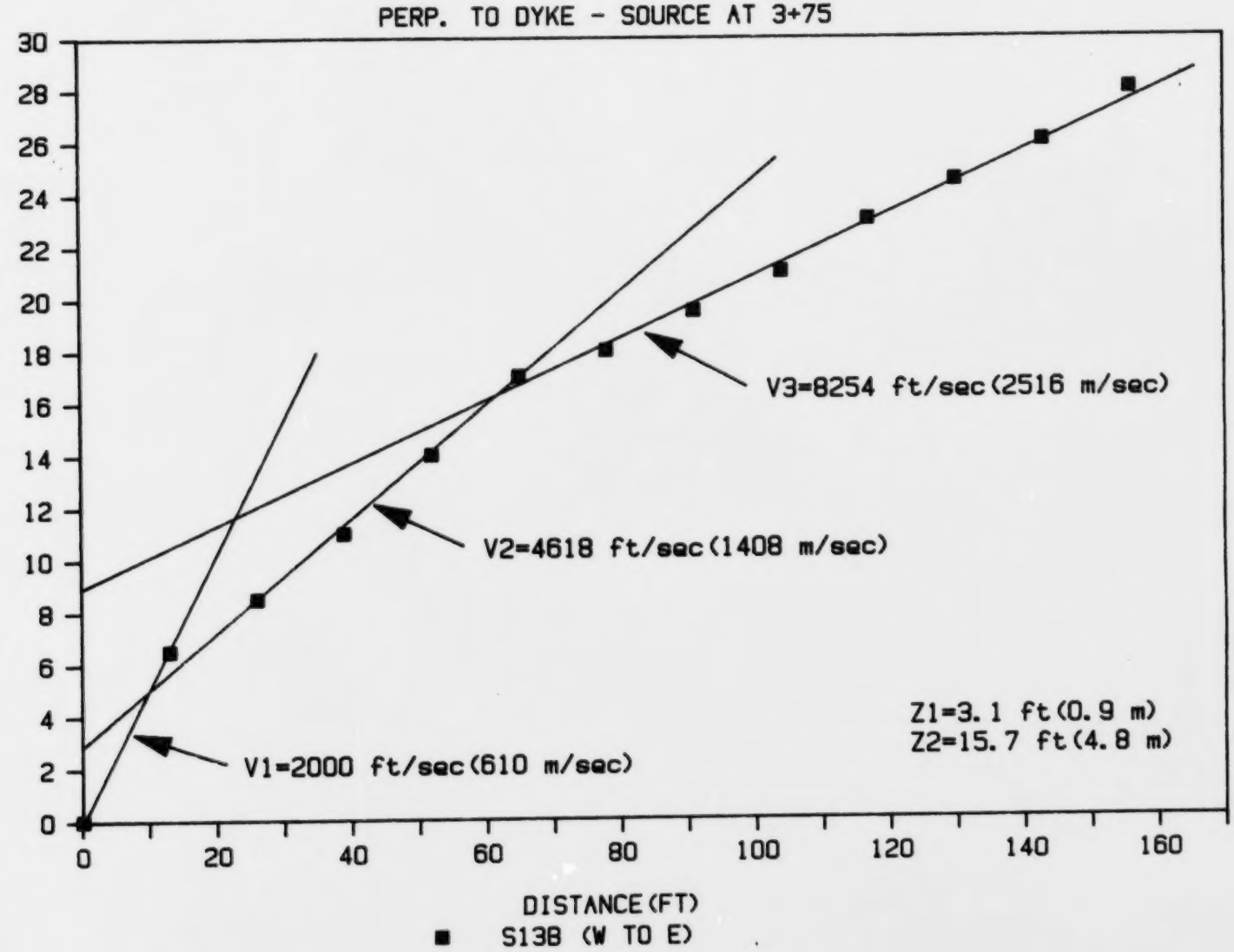
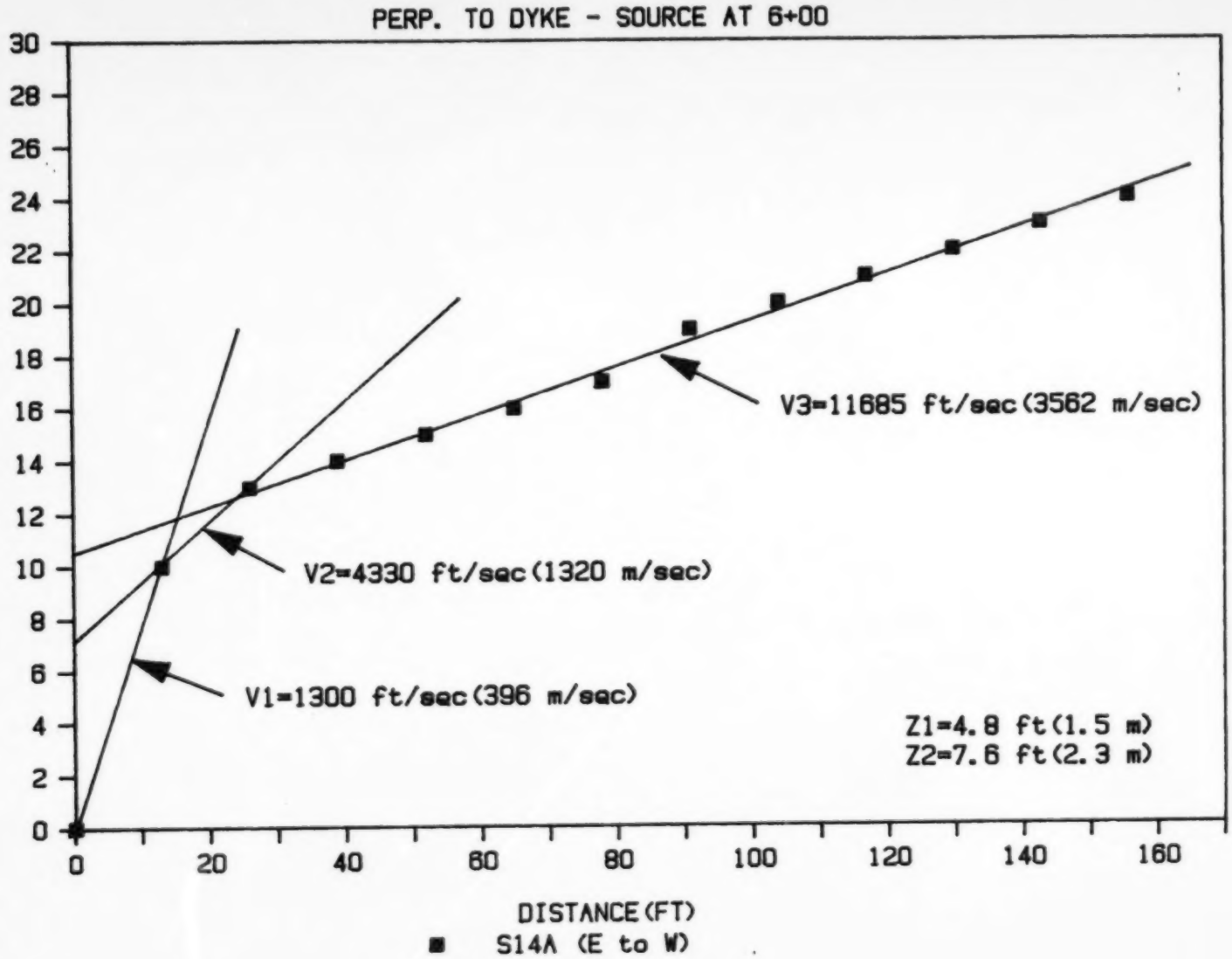
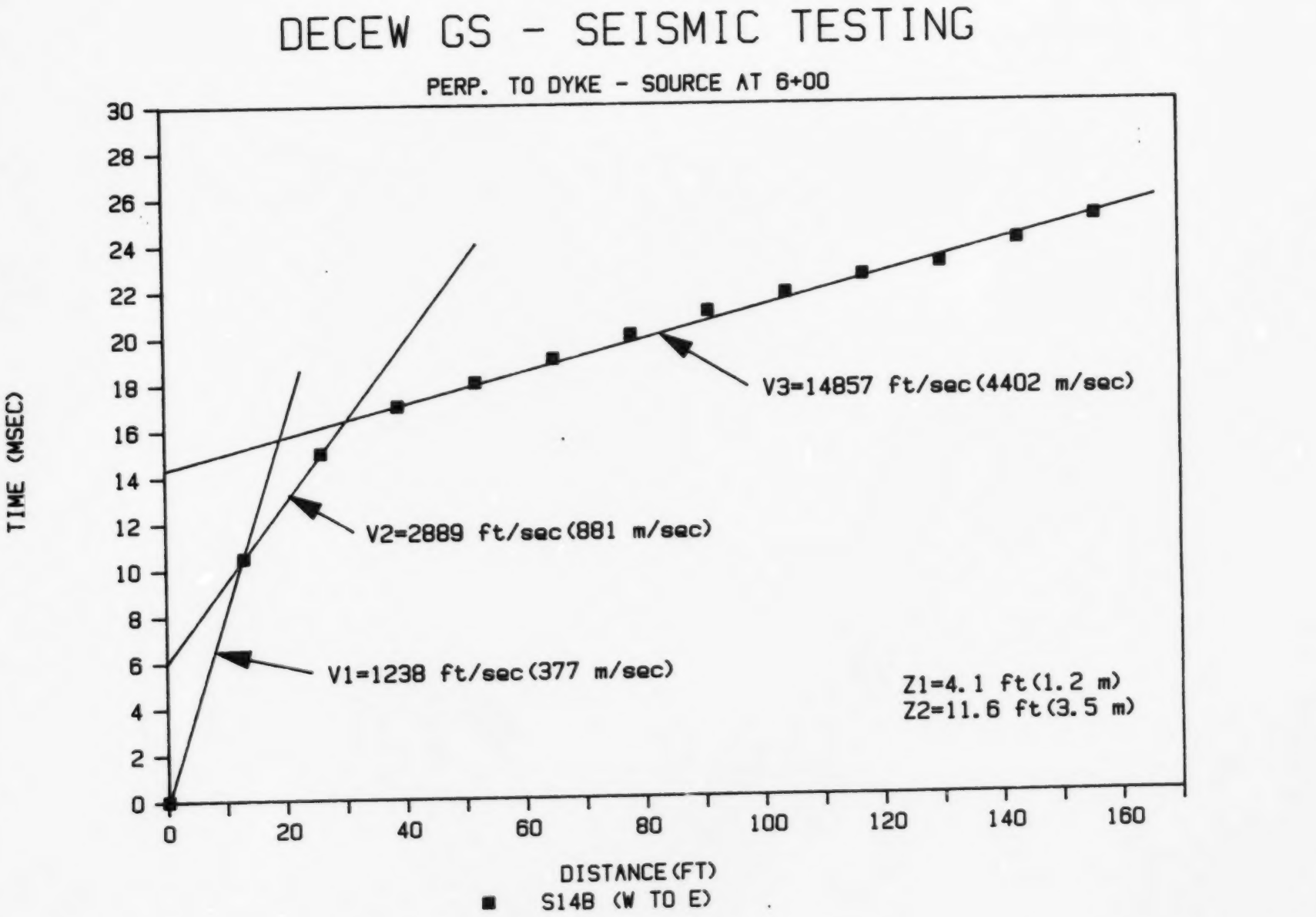
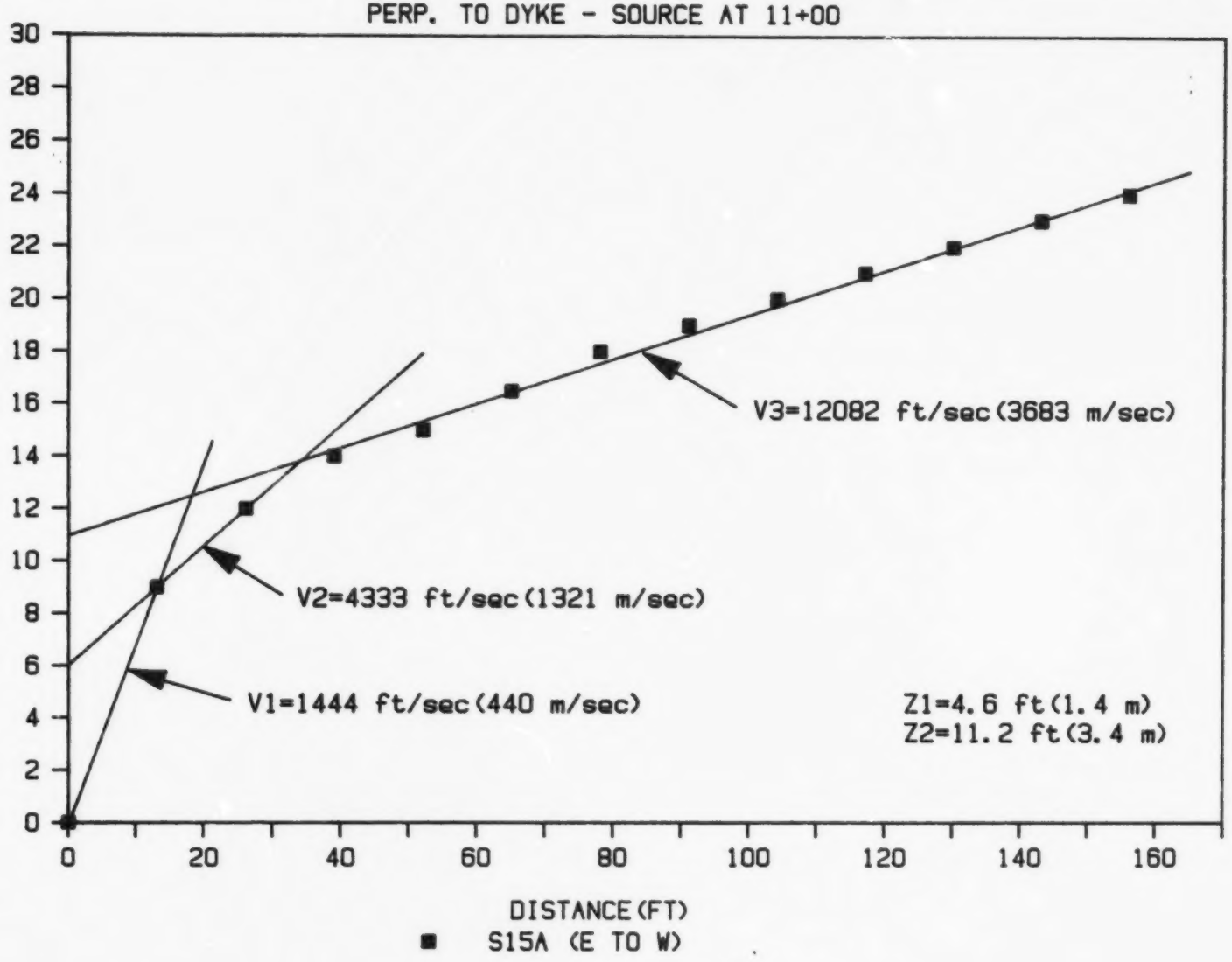


DECEW GS - SEISMIC TESTING

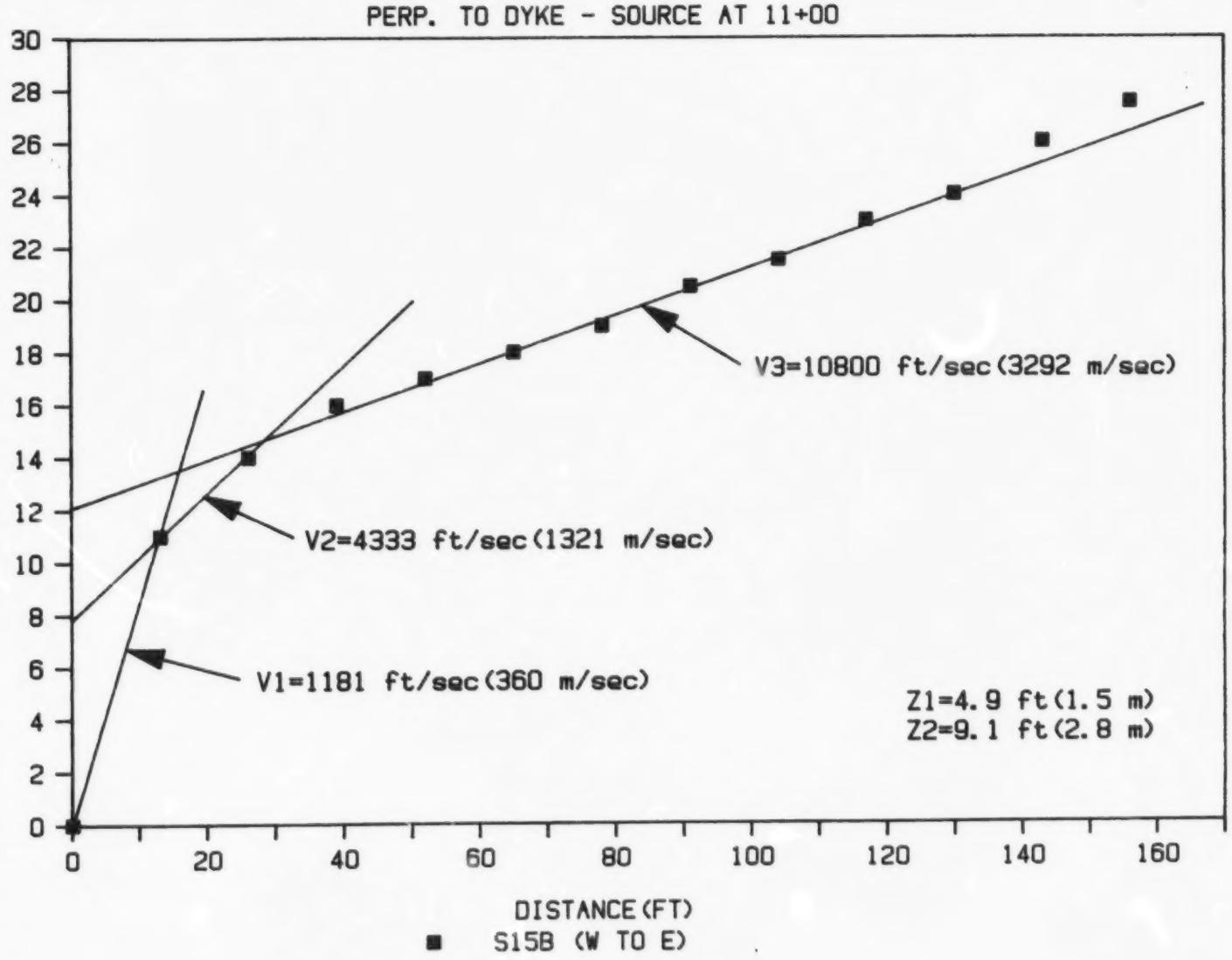



DECEW GS - SEISMIC TESTING
PERP. TO DYKE - SOURCE AT 6+00
TIME (MSEC)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
100
120
140
160
V3=14857 ft/sec(4402 m/sec)
V2=2889 ft/sec(881 m/sec)
V1=1238 ft/sec(377 m/sec)
Z1=4.1 ft(1.2 m)
Z2=11.6 ft(3.5 m)
DISTANCE(FT)
S14B (W TO E)

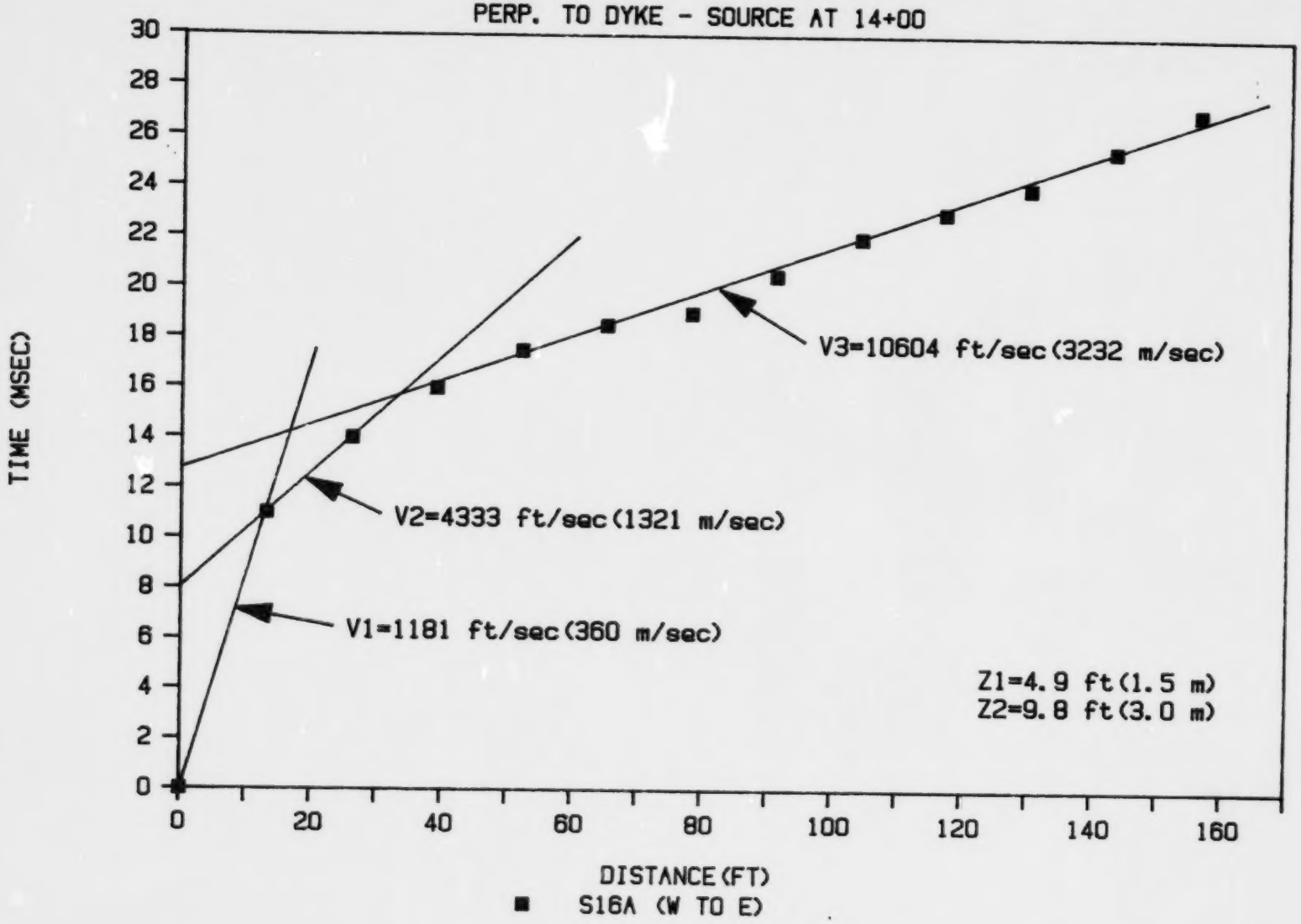
DECEW GS - SEISMIC TESTING



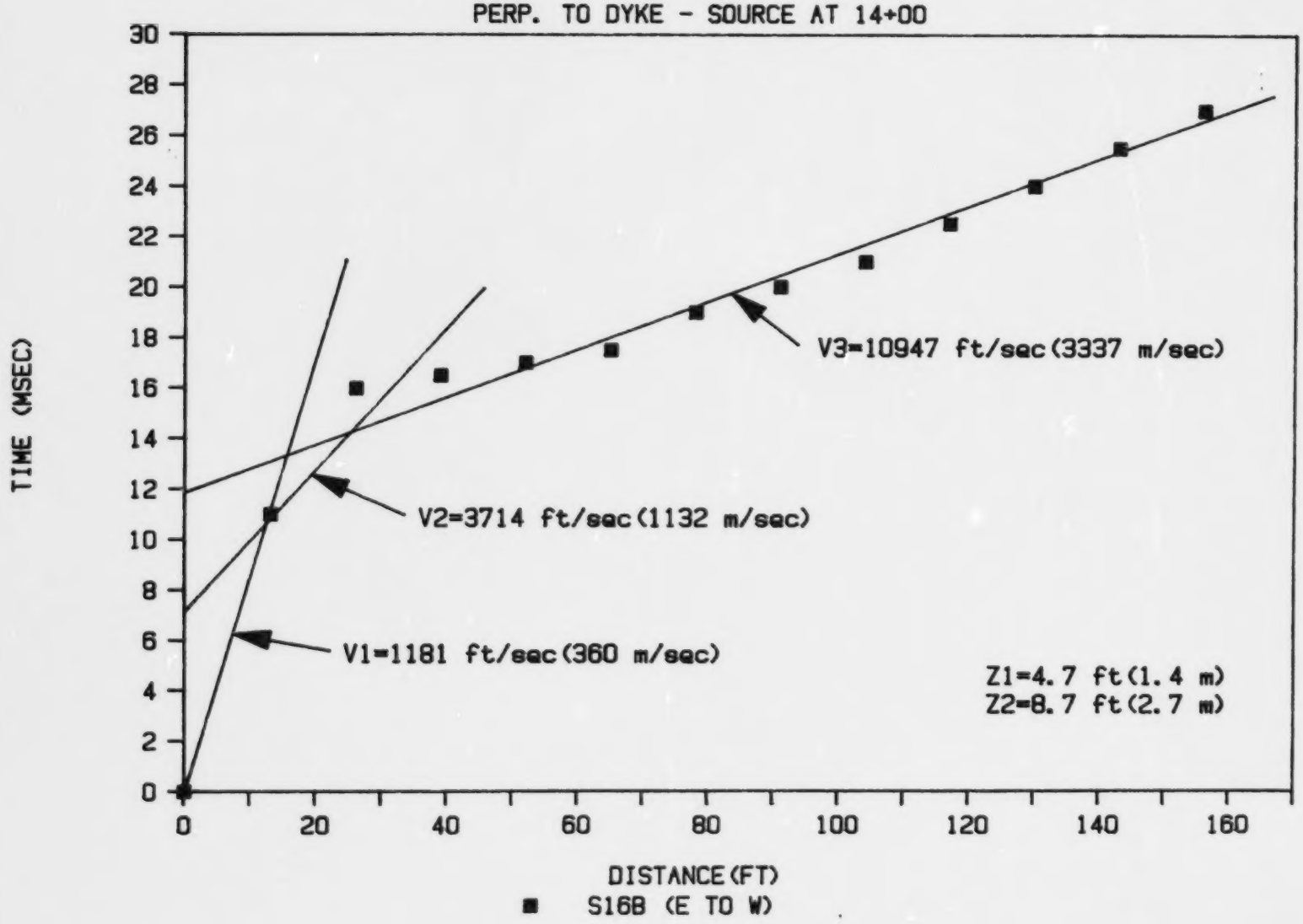
DECEW GS - SEISMIC TESTING



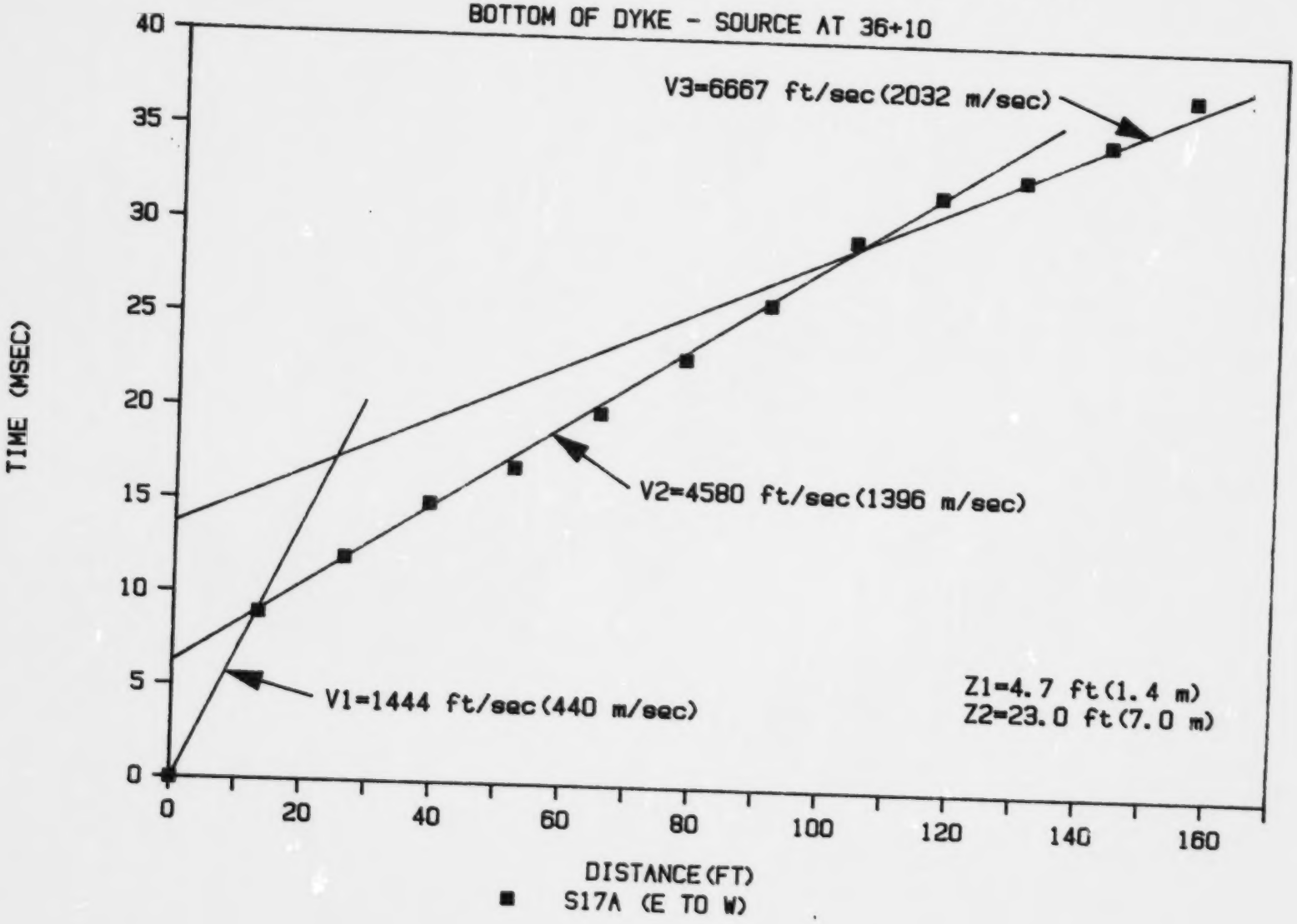
DECEW GS - SEISMIC TESTING



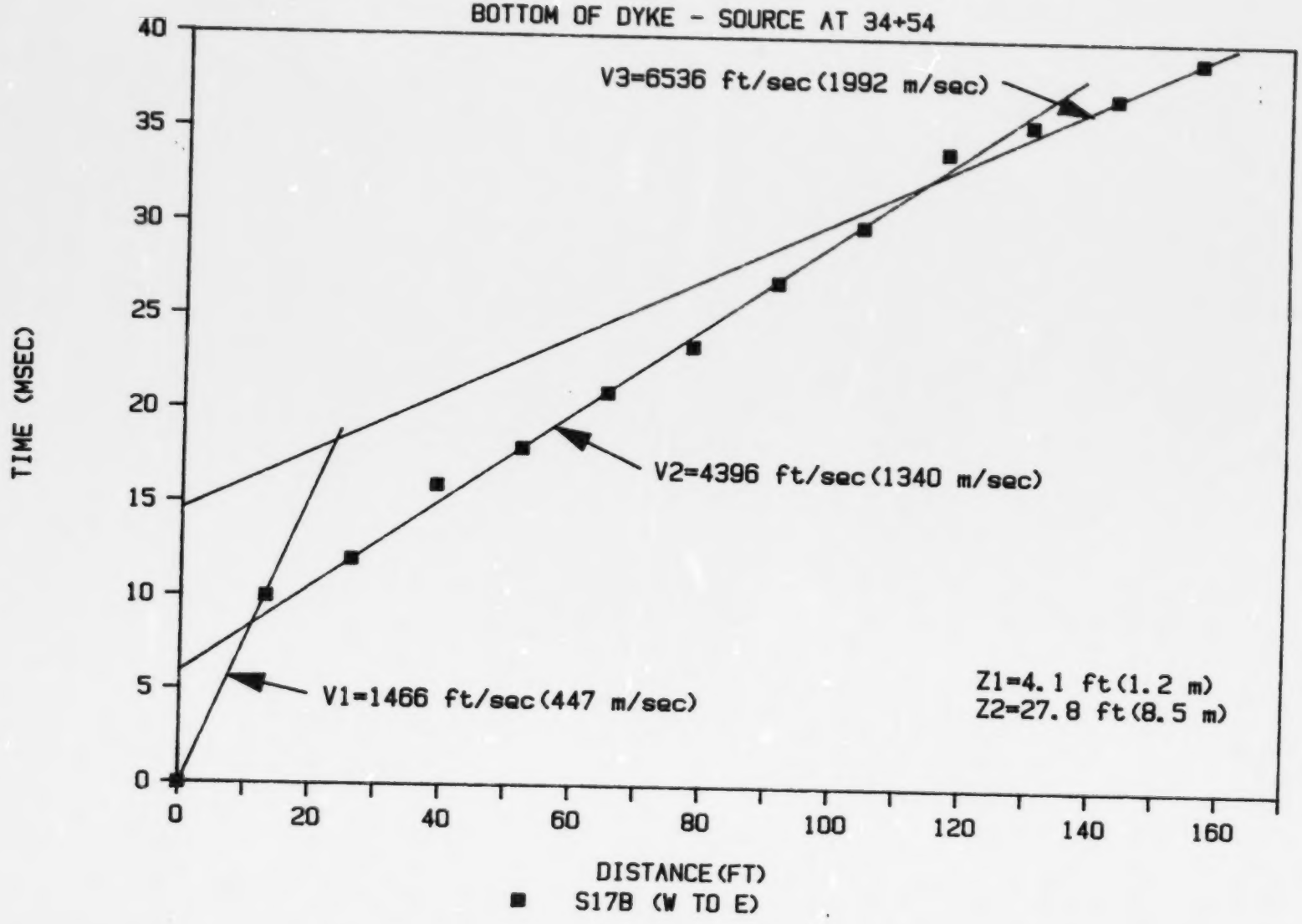
DECEW GS - SEISMIC TESTING



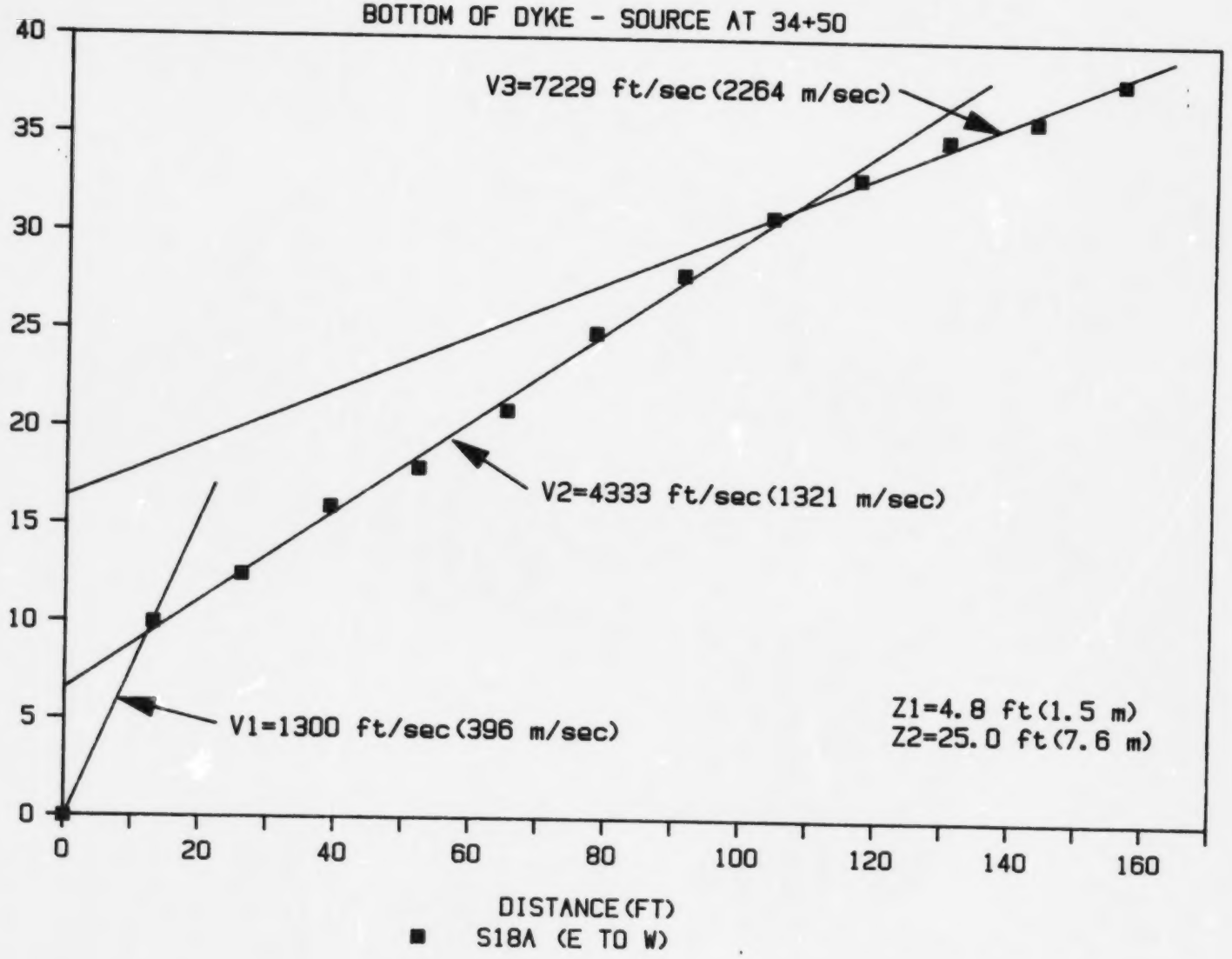
DECEW GS - SEISMIC TESTING



DECEW GS - SEISMIC TESTING



DECEW GS - SEISMIC TESTING



DECEW GS - SEISMIC TESTING